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SCIENCE READERS.

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FOR

STANDARD IV.

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PROFUSELY ILLUSTRATED.

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PREFACE.

LIKE the First Science Reader, this little book is intended to be an instrument for the "formation of habits of exact observation, statement, and reasoning," as the Code of 1883 so well expresses it.

As a Reading book it furnishes exercises in variety of expression and intonation, which are certainly not to be found in the ordinary little science manuals.

As a Science book it forms an easy introduction to physics and biology.

As an educative agent it will, the author hopes, prove effective in helping to develop in the child a mental force that shall fit him, in after life, to take a good place among his fellow-citizens, and at the same time enable him to understand and appreciate some of the beauties of the world in which he is to pass his life.

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ELEMENTARY SCIENCE.

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CHAPTER I.

MATTER AND ELEMENTARY BODIES.

IN nearly all the great towns and cities of England, there is to be found a Museum.

In London we have the British Museum, the finest *in the world.* Here may be seen, among other

things, a magnificent collection of stuffed birds. But one always feels, when looking at the glorious creatures, so natural and so life-like, that one thing is wanting. Here, for instance, a thrush is represented as if pouring out its sweet song, and filling the woods with its melody. But where *is* the song? Alas! we cannot keep *that* in a glass case. All those beautiful forms are silent. We can have the bird, its nest, and its eggs, but we cannot preserve a single fragment of its sweet song. Why not? This is the reason:

The bird or the eggs can be handled, carried about, or packed in a box to be looked at again and again, as often as we choose. But you cannot take hold of a piece of sound, nor carry it about, nor even weigh it. You cannot pack away in a box a single note of the song of the thrush, and come and hear it again any time you like.

And it is not only so with sound. It is the same with light and heat. From Spain, Italy, and South France we get vast quantities of delicious fruits. Italy sends to London ship-loads of grapes; but she cannot send us, for our dull, foggy days of November, any of that bright Italian sunshine in which those grapes ripened.

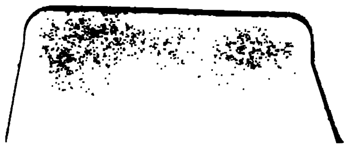
You will notice, then, that there are some things that can be handled, carried about, weighed, and which take some kind of shape; while there are others that can neither be weighed, handled, nor *fashioned into any* form whatever. The former

are called "MATERIAL" things, and the latter, "IMMATERIAL."

All material things are considered to be made up of MATTER of some kind or other. Chalk is a material thing; it is composed of matter, and has weight. Sound, light, and heat are immaterial things; they are not matter, and have not weight. The amount of matter in any thing is measured by its weight. Thus 2 lb. of chalk contain twice as much matter as 1 lb. of wool. You see this amount does not depend upon size, for very likely 1 lb. of wool takes up more room than 2 lb. of chalk.

It is very certain that there must be different kinds of matter. You may be sure the matter of coal is not the same as that of milk. It is quite clear that the matter which constitutes water cannot be the same as that of iron.

We are now coming to a very interesting subject, and may well ask ourselves some important questions: Are there really different kinds of matter? If so, how many? How can they be known? Does more than one kind enter into any object? Is chalk, for instance, made up of different kinds of matter? And if it is, how can we get at them? Does one kind of matter, or several kinds, constitute salt? If the latter, how can we tell this? Can we separate chalk or salt into their different kinds of matter? Any boy or girl can easily see that unless we are able to answer such questions as these, we shall know very little indeed about



cinder, and is really a piece of coke. We will break a corner off and hold it in the flame of the lamp. It does not give out any smoke nor burst into a flame as the coal did.

Now let us try and understand what is the meaning of all this. It is very clear that coal is made up of at least two different kinds of matter, one of which has issued from the coal as a gas, and the other is coke. Also that chalk is composed of two kinds of matter; one is an air or gas, that will put out a lighted match, and the other appears to be lime. And as to the lime, it seems to consist of nothing but lime, or of only one kind of matter. But this is not all.

While we have been making these discoveries, the bowl of coke has been for a few seconds in the fire again. Now, upon smelling it, we perceive there is sulphur in the coke. This cinder, therefore, is made up of at least two different kinds of matter, one of which is sulphur. By-and-by I will show you that the air or gas that was burnt out of the chalk is really composed of two quite different kinds of matter, and one of these, strange though it seems, is almost the same as coke. But the lime that is left from the chalk consists of only one kind of matter; we cannot discover anything in it but the substance we call lime. It is the same with sulphur. If we were to separate the sulphur from the coke, we should not find in it anything but the substance we name sulphur. In the case of the air burnt from the chalk, which

we have just found to be composed of two kinds of matter, neither of these can be further separated or divided into unlike substances. When we are finding out in this or any other way what kind of matter it is that enters into the composition of the objects around us, we are said to be "analyzing." For instance, we have been analyzing coal and chalk. But we have come to some things that we can analyse no further, such as lime and sulphur. Substances like those, that consist of only one kind of matter, are called "elements," or "elementary bodies." Pure *lime* is an element, so is sulphur.

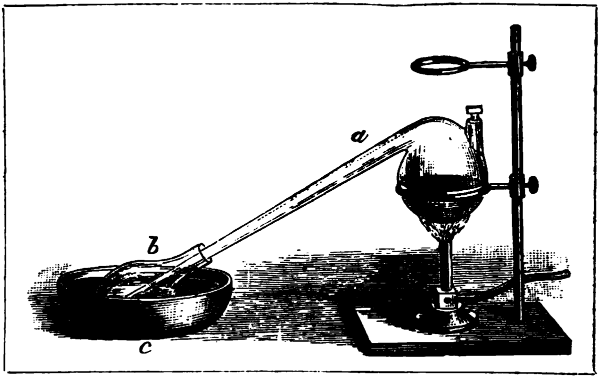
Perhaps I ought to tell you that ordinary lime is not strictly speaking an element, for it always contains a body called "oxygen." The pure lime itself has a name which I do not wish to tell you at present. So you must understand that it is the simple or elementary body I mean, when I use the word "lime."

That part of the gas coming from the burning chalk, which I told you is nearly the same as coke, is an element. It is called "carbon." The other part of the chalk-gas is likewise an element. It is called "oxygen." The coal-gas is composed of two elements, one of which is carbon and the other is called "hydrogen."

There are in all sixty-six elements. You have already read, when in Standard III., about *the three kingdoms* of nature. Well, every object, *whether* mineral, vegetable, or animal, is made up

of one or more of these sixty-six different kinds of matter.

Everything is matter that has weight, shape, and can be handled and carried about. Sound, light, and heat are not matter. An element is matter of one kind only. Most bodies consist of more than one element. A substance may be separated or analysed into its elementary parts. There are sixty-six elements.



SIMPLE APPARATUS FOR DISTILLATION.

a, A long-necked retort. *b*, A flask. *c*, Basin of cold water for condensing steam.

CHAPTER II.

THE MOST COMMON ELEMENTARY BODIES.

WE have seen that there are sixty-six elements. It is not necessary that I should describe *all* of them to you now; but there are a few that must be understood before you can form a clear idea of the nature and properties of any of the objects around you.

First I must tell you that all the pure metals are elements. Iron, silver, lead, tin, copper, zinc, gold, and many others are all elementary bodies. Of course you will understand that such metals as brass, bronze, gun and bell metals, German silver, and the like, are *not* elements; for you read in the *First Science* Book that these are mixtures *of some of the other* metals. They are called "alloys."

The most common of all the elements is "OXYGEN." It forms a part of the air we breathe and the water we drink. There is not a single article of food that does not contain, among other things, oxygen. It enters into the composition of every plant and animal, and forms about one-half of the entire substance of the solid earth. So that you can easily see that before we can understand much about rocks or plants or animals, we must know something of oxygen. In order to know something about it, we must get some and examine it. Now pure oxygen by itself does not exist in nature. So we must find out some substance or body which contains oxygen, and then separate it from the other elements of that body. When we obtain oxygen in this way it is always in the form of a gas.

I will tell you the easiest way of doing this. Buy from the chemist threepenny-worth of a substance called "potassic chlorate." It is white and crystalline, and contains a large quantity of oxygen. Put a little in a clean empty oil flask with a little sand or powdered glass. Get a cork that nicely fits the neck of the flask. Bore a hole through the cork just large enough for a piece of glass pipe to go through. You can buy one penny-worth of this glass tube of any chemist. It can be easily bent any shape you wish, by holding it in the flame of a lamp.

The best lamp for the purpose is a spirit-lamp. I have seen little glass lamps with tin tops and

wick complete for one penny. They are intended for oil, but they will do very well for spirit. You can buy as much spirit as you need at any oil-shop for a penny. Ask for "methylated" spirit. Now, if you have the flask and tube ready, you will want a basin of clean water and a tumbler. Light your lamp; and this little picture will show you how to arrange your apparatus.

APPARATUS FOR THE PREPARATION OF OXYGEN.

Hold the flask over the lamp, dip the end of the tube in the basin of water, and you will soon see little bubbles of air rising. This is, however, the common air from the flask, which the heat of the lamp is driving out. After about thirty seconds, all the air will have been driven out, and then the little bubbles that succeed will be oxygen. With your other hand, dip the tumbler down sideways into the basin, so as to get it filled with water. *Turn it* upside down, still keeping its *mouth under* water; you need not be afraid the

water will run out. Now bring the end of the glass tube just under the tumbler, and you will see the bubbles of oxygen rise into it. At the same time the water that filled the glass will gradually sink; its place being taken by the gas. The tumbler is now full of oxygen. You can now blow out the lamp, remove the flask, and set it down on the table. Place a piece of card or glass or slate over the open end of the tumbler, and remove it from the basin. Set it down on the table. Now that we have a glass of oxygen, we will try and find out something about it. In the first place, we see nothing whatever *in* the glass. Therefore oxygen gas is colourless and transparent. But perhaps you will ask, " How do we know there is oxygen there at all, the tumbler appears to be empty?" Well, light a match, and then blow it out so as to leave just a spark or two on it. Gently remove the card from the top of the tumbler, and hold the match with the spark on it down in the glass. At once the match blazes into light again, and burns much brighter in the oxygen than in the air. Do the same with a piece of paper.

If you have a little piece of one of those small candles you see in the shops at Christmas time, you can fix it in a piece of wire and let it down into the oxygen. The taper will burn *very* brightly indeed.

I do not think you will be able to perform *any other experiments* with the gas, for it will

go out of the glass into the air: not because oxygen is lighter than air, for it is slightly heavier; but because, when any different gases come together, there is always a tendency for them to mix.

Now we have learned three things about oxygen: First, it is a gas; Second, it is transparent, colourless, and a little heavier than air; And third, things will burn very brightly in it. This last fact is expressed by saying, "Oxygen is a supporter of combustion."

The most important property of oxygen, however, is the ease and readiness with which it unites with nearly every other element. It seems to be always entering into the closest friendship with every other kind of matter. For instance, if you leave a few iron nails about, they become rusty. Rub off some of this rust on to your finger, and it is seen to be a red powder. This rust is simply oxygen and iron. Some of the oxygen from the air, or from the water in the air, has united with the iron, and formed this red substance, which we call oxide of iron. If you were to burn some slips of zinc in oxygen, the metal would change to a white powder, which is oxide of zinc,—formed from the union of the oxygen and zinc. If your teacher were to place a small piece of phosphorus on a plate, the oxygen from the air would unite with it so rapidly as to produce heat enough to send the phosphorus blazing away, and making a cloud of white smoke

which is nothing but thousands of little particles of a substance composed of phosphorus and oxygen.

Next to oxygen, the most common element is "CARBON." In the last chapter you read that "coke" is nearly pure carbon. Coke, you know, is the cinder left after burning coal in a closed place. Well, if you burn wood in the same manner, you get charcoal. Now charcoal,—or as it would be better named, char-wood—is also nearly pure carbon.

But perhaps the purest form of carbon we commonly meet with is the "lead," as it is called, in lead-pencils. It is wrong to call this substance lead. Lead is the metal of which gas-pipes and other like things are made, and is quite a different thing from carbon, which is not a metal at all. It would be better to call the grey, smooth substance in lead-pencils "graphite" or "grapholite," which means "writing stone."

Again, soot is nearly pure carbon; so is lamp-black from which Indian Ink is made.

The purest carbon, however, exists only as a beautiful crystal. It is that valuable gem, the diamond. But although we do not meet with uncombined carbon in nature, yet it forms a large part of every plant and every animal, as well as nearly every rock. In fact, we may say that by far the greater part of our earth, and of all living things upon the face of it, is made up of the two elements, carbon and oxygen.

Before we go on any further with our elementary bodies, it would be well to notice a very important substance which is composed of these two elements, carbon and oxygen, united in such a way as to form a compound.

You have seen that a lighted taper burns very brilliantly in oxygen; but if we had previously allowed a piece of charcoal to burn itself quite out in the gas, and *then* introduced the taper, we should find that, instead of burning brightly, it would be quite extinguished.

This shows that the oxygen has undergone a complete change. It is not at all difficult for you to understand exactly what has happened.

The charcoal, which you know is nearly pure carbon, has united with the oxygen, and formed another gas altogether different. In common language, we should say the oxygen has all gone, and part of the charcoal has gone, having been burnt away. But in reality neither of them has gone. The whole of the oxygen in the glass has taken up as much of the carbon as it could, and formed a gas, which we commonly call "CARBONIC ACID." So that the glass is filled with carbonic acid gas. This gas will not support combustion. A lighted candle goes out directly it is placed in it.

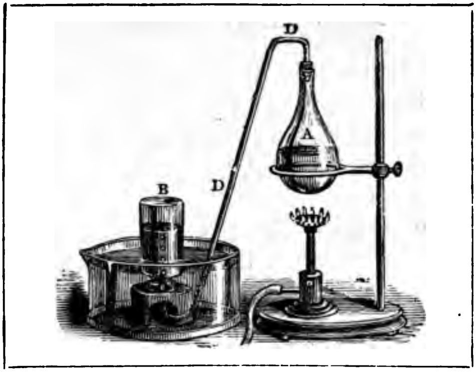
You will remember that when chalk is burnt, there comes from it a gas which puts out a lighted match; and that what is left of the chalk *after burning* is lime. This was described in

Chapter I. Well, the gas that is driven from the chalk by heat is carbonic acid. And chalk is simply lime and carbonic acid, and is therefore termed " carbonate of lime."

All limestones, even white marble, are, like chalk, composed of these two ; and when limestones are burnt in lime-kilns, it is the gas that is burnt out, and the lime left.

We shall have more to say about this carbonic acid, when we come to speak of the lungs of animals and the leaves of plants. At present I will only add, that it is a very heavy gas ; is given out by all animals in the act of breathing ; and is thrown out in large quantities by volcanoes. It is also produced whenever substances containing carbon are burnt in the air or in oxygen.

Oxygen is the most abundant of the elements. It supports combustion, and readily unites with other elements. Carbon is also an abundant element. A certain quantity of oxygen in union with carbon forms the compound, carbonic acid gas. This is a heavy gas, and does not support combustion.



APPARATUS FOR THE PREPARATION OF A GAS.
A, Flask containing solution. B, Receiving bottle. D, Bent tube.

CHAPTER III.

ELEMENTARY BODIES (*continued*).

YOU read in the first chapter of this book, that when coal is burnt in any closed chamber, such as the bowl of a tobacco pipe or the iron retorts at the gas-works, a gas is obtained that burns brightly. This is the gas which is used to light our streets and dwellings, and is chiefly composed of the two elements hydrogen and carbon, united together. When it is properly obtained and purified, it burns with a white flame. The whiteness is due to the carbon, which is present in countless particles. These particles of carbon become white hot in the burning hydrogen. If we were to burn hydrogen itself, we should find that its flame is very pale, almost invisible. It *gives very* little light, but abundant heat.

I will tell you how hydrogen may be obtained; though I should not advise you to try and make any yourself, for, when mixed with air and lighted, it explodes with great violence, and might possibly cause an accident.

A small quantity of zinc clippings is put into a bottle having a cork bored to receive a pointed glass tube. A little oil of vitriol or sulphuric acid is mixed with six or eight times its bulk of water. The cork with its pointed tube is taken out of the bottle, and some of this diluted acid is poured on to the zinc. The cork is then replaced, and in a few seconds hydrogen comes rushing out at the point of the tube. It can be lighted, after sufficient time has elapsed to allow all the air to be driven out, and is then seen to burn with the pale flame of which we have just spoken.


HOW TO OBTAIN HYDROGEN.

Now where does this element hydrogen come from? Certainly not from the zinc, for that is itself an element. Not from the sulphuric acid, for that is composed of the two elements oxygen and sulphur. But there is nothing else in the bottle but the water that was mixed with the acid. Therefore this element, hydrogen, which we have seen is an inflammable gas, has really been obtained from water.

Hydrogen is, therefore, one of the elements of water. It is an exceedingly light gas, much lighter than air. It is for this reason that balloons are inflated with hydrogen.

But what is the other element of water? A very simple experiment will enable us easily to answer this question. If we cause water in the form of steam to pass in at one end of a white-hot iron pipe stuffed with small iron nails, we should find, issuing from the other end of the pipe, pure hydrogen gas. Then if we were to turn the nails out of the pipe, they would be found quite rusty. Iron rust, as we have before described, is oxide of iron, or iron in union with oxygen. From this experiment therefore it is seen that water is composed of the two elements hydrogen and oxygen. This is an important fact, of which we shall have more to say when we come to describe the food of plants.

In the last chapter, you read that the element oxygen forms a part of the air we breathe; but it forms a small part only, not more than one-fifth. We will now endeavour to find out the composition of the remaining four-fifths.

To do so, we must have a basin of water, a tumbler, a little piece of phosphorus, and a very small iron or tin saucer, that will float in the basin of water. I place a small piece of phosphorus about the size of a pea in the saucer, and let it float. I then, with a hot wire, just touch the phosphorus, which immediately bursts into a

flame. The tumbler must at once be turned upside down over the saucer, so that the rim of the glass is in the water. In a few seconds, the phosphorus flame goes out, and it is observed that the water has risen a little way up into the tumbler; in fact, about one-fifth of the distance. The remaining portion of the glass is filled with a white smoke, which, however, soon settles, or appears to go quite away, and a clear space is left.

Now what is the meaning of all this? What a number of questions we want to ask and get answered!

Why did the phosphorus burn? Why did it go out? Why did the water rise in the tumbler one-fifth of its depth? Why did it rise at all? What was the white smoke? Why did it disappear, and where has it gone? What is there in the clear space of the tumbler? Is it air, the same as at first?

Some of these questions we will at once answer, others must be left for the present. Let me remind you of two facts you have already learned. First, there is oxygen in the air; second, phosphorus unites readily and rapidly with it. Now when the phosphorus was burning inside the tumbler, it was really taking up the oxygen from the air, and forming with it the white smoke that filled the glass. When all the oxygen had been *taken up, the* phosphorus flame went out. The *"burning"* was, in fact, nothing but the oxygen

uniting with the phosphorus; and when there was no more oxygen to unite, then the "burning" stopped. The white smoke was simply myriads of particles of a snowy substance made up entirely of oxygen and phosphorus. These particles, in time, sank down into the water, leaving the space clear inside the tumbler. The water rose in the tumbler to occupy the space previously taken up by the oxygen. Why the water did so, we must leave for the present.

As the water rose in the glass one-fifth of its depth, it is proved that oxygen must have occupied that one-fifth. But the tumbler was, in the first place, full of air. Therefore it is very clear that one-fifth of the bulk or volume of the air we breathe is oxygen.

But what are the other four-fifths? Except a very small portion indeed, these four-fifths are a gas called "NITROGEN." So that we may state that common air is composed of one-fifth of oxygen and four-fifths nitrogen.

Nitrogen gas neither burns nor supports burning. It has no colour, taste, nor smell; yet it is a very important element. Bread, milk, and meat contain nitrogen. The ammonia in the air, which, although very small in quantity, is yet so useful for plants, consists mainly of nitrogen.

Now that we have described a few of the commonest elements, it will be well for us to say something as to the way in which *they unite with each other.* You have seen that hydrogen and

oxygen are gases, and yet when they are united in a certain manner, we get water, which is not a gas, but a liquid. The properties of water are quite different from those of either hydrogen or oxygen ; for water is neither inflammable nor a supporter of combustion. It is, in fact, a totally different thing from either of its elementary parts.

Again, carbon, as we generally see it, is a black, solid substance, and oxygen is an air or gas, which supports combustion ; yet the union of these two elements in a particular manner, gives us carbonic acid gas, a totally different body from either carbon or oxygen.

On the other hand, the air we breathe, which, we have seen, is mainly composed of nitrogen and oxygen, still retains the properties of those elements. The oxygen in the air is unaltered by its contact with the nitrogen, and the nitrogen by its contact with the oxygen.

You know that phosphorus burns very brilliantly in oxygen, because of their rapid union ; but phosphorus also burns in common air, and for exactly the same reason,—the oxygen of the air so readily unites with the phosphorus. Hence we learn that the oxygen in the air still retains all its properties.

Now when elements are brought together in such a manner that they do not lose their respective characters, we call such a union a *mixture.* The *air is therefore* a mixture of gases.

But when elements are united in such a way

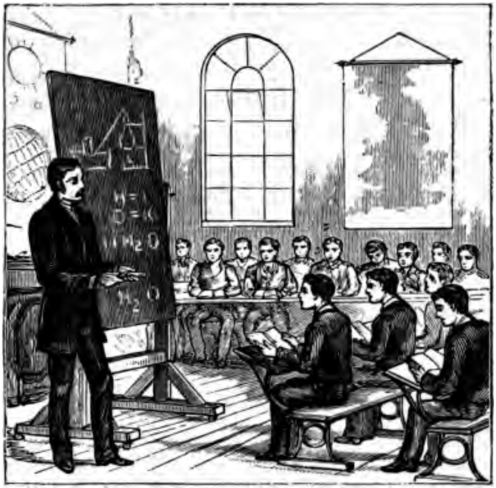
that they *do* lose their properties, and by their union form a totally different substance, we call such union a *compound*. Thus water and carbonic acid are compounds.

I will give you another illustration. If I mix up together white sand, pearlash, soda, and red lead, I get a red-looking, coarse powder; and if I place a little of this powder under the microscope, I can easily distinguish the grains of sand as well as the particles of the other substances. Neither of these things have at all changed their character by being brought together in this way. But if this red powder be greatly heated in a furnace, all the different materials unite and form beautiful clear glass, in which neither sand nor red-lead nor soda nor pearlash can be detected. Glass, therefore, is a compound.

Now we have described a sufficient number of the elements for our present purpose. We will, therefore, only just mention two or three others, without entering into any particulars about them. Flint consists mainly of the mineral "silica." Now silica is made up of the element oxygen and another element called "SILICON." Soda consists of the element "SODIUM" and oxygen. We have called "lime" an element; but, strictly speaking, lime, as we always find it, is composed of the element "CALCIUM" and oxygen.

Hydrogen is one of the elements. In *its ordinary* state, it is an inflammable

gas. Nitrogen and oxygen form co mon air. Elements, when broug together, form either mixtures or co pounds. The air is a mixture. Wa is a compound of hydrogen and oxyg



MASTER SHARPENING A PIECE OF CHALK.

CHAPTER IV.

PHYSICAL PROPERTIES OF MATTER.

IN Chapters I., II., and III., we have been describing the composition of certain substances. We have seen how elements may combine to form mixtures and compounds; and how compounds may be analysed or broken up, as it were, into their elements. All this kind of knowledge goes under the name of *Chemistry*.

Anybody who wishes to understand clearly the nature and properties of any mineral or vegetable or animal must know something of Chemistry.

Of course, in these three chapters you hav

learned only a very little of chemistry; still, if you have really understood what you have read, you will, I think, know as much of it as is necessary for our present purpose.

But there are many other important and interesting things to be learnt respecting the objects around us besides their composition.

For instance, we write on the black-board with chalk; it would be quite useless trying to write with a piece of white marble. Now, so far as elementary composition is concerned, Chemistry tells us that chalk and white marble are exactly alike; both are carbonate of lime. There must consequently be some difference between chalk and marble which does not depend upon the character of the elements of which they are composed.

Again, water, when heated, becomes steam; or, when cooled below a certain point, becomes solid ice.

Now the liquid water, the gaseous steam, and the solid ice are precisely alike in their elementary composition. They are, as you know, each composed of hydrogen and oxygen. And yet each of these things has properties of its own. For instance, steam can be easily compressed or squeezed into a small bulk, and, when the pressure is removed, it returns to its original bulk. Hence we say steam is *elastic.*

But under ordinary pressure, water cannot be compressed in the smallest degree; it is inelastic.

It is easy to see that the elasticity of steam and

the inelasticity of water have nothing whatever to do with their elementary composition.

If a rod of iron be heated, it expands and becomes longer. This is not because the rod is composed of the particular element "iron," for all metals expand by heat; so, in fact, do liquids and gases.

If I spill some water, it falls to the ground; certainly not because it is composed of the elements hydrogen and oxygen; for every material body has a tendency to fall to the ground.

We are therefore beginning to see that substances have certain properties that have nothing to do with their chemical composition. We should be able to understand the expansion of substances by heat, the elasticity of steam, and the weight of bodies, even if we knew nothing whatever respecting the elements of those substances. While, on the other hand, we could not understand the rusting of an iron nail in water, unless we knew that water was composed partly of the element oxygen; and that iron rust is iron in combination with oxygen. Also it would be impossible to explain some of the properties of coal if we were ignorant of its chemical composition.

It is very clear, then, that substances have at least two distinct groups of characters: one of which is due to the nature of their elements; while the other group concerns the condition of the body as a whole. The former we may term "*chemical properties*," and the latter, "*physical properties*."

For instance, the air we breathe is a supporter of combustion. This is a chemical property of the air, for it is due to the presence of oxygen.

Again, air is expanded by heat. This is a physical property; it has nothing to do with the fact that air is composed of nitrogen and oxygen; for expansion by heat is a property possessed in a general way by all bodies.

Let us try and understand two or three of these physical properties of matter. To do so, we will begin with a little incident that you probably see every day of your life; I mean, your teacher making a point to a stick of chalk with his penknife.

You know he does this by scraping one end of the stick, when the particles of chalk come off and fall to the ground. Very likely some of you will say, "There is nothing particularly wonderful about that."

But I should like to ask you three questions about these particles. First, What made them come off the stick? Second, Why did they fall to the ground when they *did* come off? Third, What held them on to the stick *before* they came off? I dare say some of you think you could very soon answer these three questions. But they are not quite so easily answered as you suppose.

At present I am not going to answer all of them, but only one. We will take the third, *namely,* "*What* is it that holds the particles of *chalk together* on the stick?"

Suppose I hold up a lump of chalk. It is, I know, made up of particles of chalk, for I can rub some off on to my finger. Chalk is matter, and has weight. That is perfectly clear. Therefore every particle, however minute, has weight. Now if the particles on the underside or at the bottom of this lump have weight, how is it they do not fall off to the ground? There must be something that keeps them together on to the block.

You know very well that if you dip your finger in water and take it out again, you will find a drop of water hanging at your finger's end. Now this drop of water consists of a very great number of the smallest conceivable drops, called molecules, all clinging together.

What keeps them together? It is this,—"the attraction of cohesion." Now I must tell you that we cannot explain what this "attraction of cohesion" really is; nobody has ever seen it. All we know is, that the particles or molecules of solids and liquids are held together, and it takes some force to get them apart. We suppose there is something holding them together, and we name this something, "attraction of cohesion."

It is very certain that the molecules of some things are held together more strongly than those of others.

For instance, I can move my finger about in water quite easily. I can dip it in and out with *scarcely any* effort. In doing so I must have *forced some* of the molecules apart. Therefore

they are certainly not held together very strongly by the attraction of cohesion. Still, the drop hanging at the end of my finger shows that water molecules have cohesion to a certain extent. But I could not dip my finger in and out of a block of chalk. Why not? It is because the molecules of the chalk are held together firmly, and so it takes a considerable force to separate them. This is the case with all substances we call solids. We may therefore say, that in a solid the attraction of cohesion among the molecules is strong; and in a liquid it is weak.

But we have read in Chapter I. that matter may exist not only as a solid or a liquid, but also as a gas. Now a body of gas, such, for instance, as the glassful of carbonic acid gas we spoke of in Chapter II., is considered to be made up, like water or chalk, of a vast number of inconceivably small particles called molecules.

Let us see how the attraction of cohesion acts with respect to the molecules of a gas.

If from that gas-pipe I allow the gas to escape into the room, every one present would, in a very few seconds, smell it. This proves, that although the gas was passing out of the pipe for a few seconds only, yet it had spread all over the room. Now this room would certainly hold over 2,000 cubic feet of gas. But during the time it was turned on, only about one cubic foot escaped. How is it then that one cubic foot of gas spreads throughout 2,000 cubic feet of space?

If we had to fill the room with water or with chalk, we should have to bring 2,000 cubic feet of it. In a cubic foot of gas there are, of course, a certain number of molecules. Are there, think you, a greater number when the cubic foot has spread over the room? No, there cannot be any more. Then what must have happened to the molecules? If we have a small heap of marbles on the table, and wish them to spread all over the table, what have we to do? We must certainly place them further apart, separate them, so as to leave spaces between.

Well, this is precisely what happens to the molecules of the gas. When that cubic foot of gas was in the pipe or in the gas-holder at the works, the molecules were all kept together by pressure. But as soon as I turned on the gas, that pressure was removed, so that the molecules flew apart from each other, and spread over the room.

You will therefore see that the attraction of cohesion, which keeps the molecules of solids and liquids together, does not exist in a gas. In fact, we observe quite the opposite of attraction, namely *repulsion.*

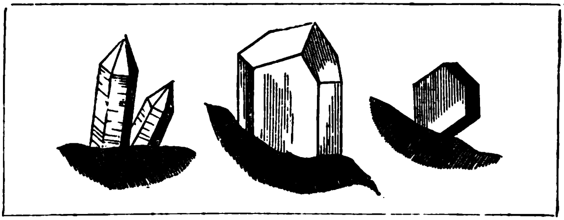
Hence we conclude that in a solid, the attraction of cohesion is strong; in a liquid, weak; and in a gas it does not exist, but there is its opposite, repulsion. One physical property of matter, in its solid *and liquid* states, is, therefore, the *ATTRACTION OF COHESION* of its molecules.

You will remember that in Chapter II. we described the burning of a piece of charcoal in a jar of oxygen gas. Nearly all the charcoal or carbon burnt away and then went out. Then we examined the contents of the glass and discovered that the oxygen had gone also; and in its place quite another gas was found.

Now, in common language, it would be said that the carbon and oxygen had both burnt away and been destroyed. But, in reality, not a single atom of either one or the other had suffered destruction. The carbon had simply united with the oxygen and formed the compound, carbonic acid gas. The "burning" was the act of uniting.

This experiment, and many others we might mention if we had time, proves that it is quite impossible to destroy a single particle of matter. We may change its state or form, but cannot destroy it. Here, then, is another property of matter—its "INDESTRUCTIBILITY."

Properties of matter are either chemical properties or physical properties. That iron expands by heat is a physical property. That it unites readily with oxygen, is a chemical property. Attraction of cohesion, indestructibility, and weight, are physical properties of matter.



CRYSTALS OF QUARTZ, FELSPAR, AND MICA.

CHAPTER V.

THE MINERAL KINGDOM—ROCKS.

If you have thoroughly mastered all that is contained in the preceding chapters, you will be able to understand the nature of many of the objects around us much better than you did when in Standard III.

You will remember that we classified minerals into rocks and metals; and vegetables into flowering and flowerless plants; and animals into backboned animals and boneless animals. Let us now carry our description and our classification just a step or two further.

We will begin with the mineral kingdom. Here I must tell you that we have been using the word "mineral" in a general sense to mean any object in the mineral kingdom; everything, in fact, which is neither a vegetable nor an animal.

But besides this use of the term, there is another sense in which it is often employed. For instance, in the First Science Reader, we described the rock called granite. This, you know, is the stone of the

kerb and of the road-way. It is called "granite" because it is made up of "grains." If you look at a piece, you will easily distinguish these grains, for they are of different colours and shapes.

In most granites there may be seen three different kinds of grains, which are really little pieces of three distinct minerals.

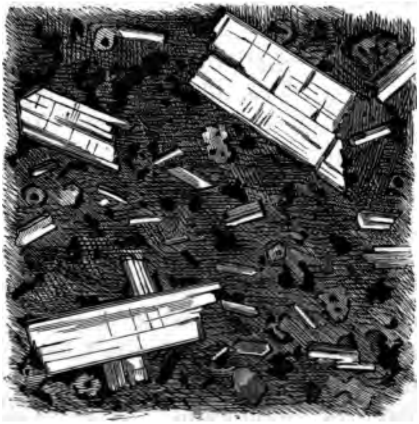
There are the little sparkling specks of the mineral "*mica.*" Then we may detect some flat, pinkish pieces, with straight sides; these are fragments of the mineral called "*felspar.*" The dull, glassy part of granite is the mineral "*quartz.*" Now, in a general sense, we may call granite a mineral, as it belongs to the mineral kingdom; yet, strictly speaking, we ought to term it a rock, and say that it is composed of the minerals mica, felspar, and quartz. By-and-by we will say more of these three minerals.

We have now three classes of substances in the mineral world—rocks, minerals, and metals. In this chapter we shall say nothing about the metals; we will talk only of rocks and of the minerals that compose them.

I am going to consider rocks as consisting, for the most part, of two great classes. In the first class we will place granite, and rocks formed from granite: in the second class we will place limestone rocks; that is to say, all rocks which, when burnt, yield lime.

We will take the granite class first, and begin *with* GRANITE itself. Any boy can easily get a

ce of granite. If he hammers it up into a ırse powder, he can separate the grains of silvery ca, glassy quartz, and pinkish felspar, and place em in three little paper boxes. I should advise u to do this, and show the boxes to your cher; he would, I am sure, be very pleased. metimes the felspar is almost white, then the ınite is of a grey colour; sometimes the felspar



SECTION OF CORNISH GRANITE.

reddish, then we have that beautiful red granite ich you may often see polished and forming y handsome monuments.

Lately some men have put up near my house a nking trough for horses. It is cut out of a ck of beautiful granite. But the felspar in it is *a milk-white* colour, and in very large pieces, *ie of them* quite an inch long. They have fla

surfaces and straight sides. The mica in that granite, instead of being silvery, is quite black, yet it shines and sparkles in the sun. The quartz fills up the space between the felspar and the mica.

There is an immense quantity of granite in the world. Sometimes whole mountains, like those of Scotland, are composed of nothing but granite. It is found that the granite of these mountains is continued deep down in the earth, underneath other rocks.

Some of you may live in houses that have gardens to them. Very likely, in digging up your garden, you come to ground under the mould that is quite different from the mould itself. It may be clay. In some places it is sand. I was once digging up a garden, and under the mould there was nothing but chalk. Well, very deep in the earth, thousands of feet under this clay or sand or chalk, there is almost certain to be granite of some kind or other. And you have just read that granite sometimes rises high above the surface, and forms great mountains. When this is the case, the rain falls on it, the wind beats against it, the frost gets at it, and the rock itself is gradually worn away. You will wonder that so hard a rock as granite should ever wear away. I will tell you how it happens.

The rain falls on the granite, and some of the water soaks a little way into it. In the winter this *water freezes.* The ice takes up more room than *the water it was* formed from. You read about

this in Standard III. This expansion of the ice breaks up the rock into a great number of very little cracks, running in all directions. When the ice in the tiny cracks melts and the water dries up, you might rub your finger across the granite, and some of the rock would really come off on to your skin in the form of coarse dust.

What is this dust? It is nothing but little grains of quartz, mica, and felspar. And if you were to look at the mica-grains through a magnifying glass, you would see that they are very little thin plates.

What do you think will happen to all this dust on the granite when the first shower of rain comes? Anybody can see clearly enough, it will all be washed away down the mountain. But where will it be washed to? Into the mountain streams certainly, and then into the rivers, and the rivers will carry it out to sea. Not all of it, perhaps. Some will settle down in the rivers, especially where the current is slow; and the largest and heaviest particles will be the first to settle. Still a great deal of it will travel on to the ocean, where it will settle and form large portions of the ocean bed.

There is, however, a very interesting fact about this that we must not pass over without notice; especially as your little knowledge of chemistry will enable you to understand it.

There is, as you know, carbonic acid gas in the *air; animals,* fires, and volcanoes are the causes

of this. Well, the rain, in falling, takes up some of this gas into itself. Now when the rain with its carbonic acid falls upon the granite-dust on the mountain, it not only washes this dust down into the rivers, but really decomposes or analyses some part of it.

We have said that dust is composed of grains of mica, quartz, and felspar. Well, the carbonic acid does nothing with the mica and the quartz, it leaves them alone, and sets to work and makes a wonderful alteration in the felspar.

Now the felspar which we usually find in granite is not an element, it is a compound body, and is made up of these four substances—silica, alumina, lime, and soda, all of which you have read of before. The carbonic acid of the rain combines with the lime, and forms our old friend, carbonate of lime, about which you have heard so much. It also combines with the soda, and forms, in like manner, carbonate of soda. This is the white-looking powder that I dare say your mothers put into the ale when it has turned sour. This being the case, there is nothing remaining of the felspar but the silica and alumina.

Now, as the soda and the lime are gone, the felspar is thus completely broken up, and the silica and alumina are left free to do as they please. I will tell you what it is they please to do. They at once strike up a close friendship with each other. In fact, they combine, and by their union form that most useful material clay.

Just think for a moment of the various things there are in the river which have all been obtained from the wearing away of the granite mountain.

First, there are carbonate of lime and carbonate of soda. These are carried straight out to sea without settling at all ; and from the carbonate of lime the oysters, etc., make their shells

Second, there are the grains of quartz and mica. Some of these sink down to the river bed, but most are borne to the mouth of the river, and form sand-banks, which, in time, become sandstone.

Third, there are vast quantities of clay. This is in such fine division, and so light, that it is carried quite out to the ocean, and there settles down, and forms vast beds.

Do you not think it very wonderful, that the clay now in your garden once formed the bed of an ocean? Yet this is true. And is it not remarkable that the flagstones of the pavement are portions of what may have been at one time great sand-banks, over which there dashed huge waves?

Here then we have two rocks, sandstone, and clay, formed from granite.

But the slate upon which you write, and which forms the roofs of houses, has once been clay. I have sometimes seen boys sharpening their slate pencils, and mixing the dust with a little water. They have then formed a dark-looking mud, which is really something like the clay that slate was before it became hardened into the rock of the

quarries. A great quantity of slate comes from North Wales.

In the next chapter we will describe the limestone-class of rocks.

The objects of the mineral kingdom may be classified as rocks, minerals, and metals. Granite is a rock, and is usually composed of the three minerals, quartz, mica, and felspar. Rocks may be divided into two groups—namely granites and rocks formed from them, and limestones. The former class includes the various forms of granites, sandstones, clays, and slate. The latter, all rocks which when burnt yield lime.

A CHALK PIT.

CHAPTER VI.

VARIOUS KINDS OF LIMESTONES.

IN Chapter II. you read that chalk is composed of lime and carbonic acid, and that when chalk is burnt, the carbonic acid is driven off in the form of a gas, the lime being left. When carbonic acid combines with lime to form a compound, we get carbonate of lime.

Chalk therefore is carbonate of lime. All limestones are for the most part carbonates of lime. Chalk is too soft a limestone to be used for building purposes. In the south and south-east of England, there are immense quarries of chalk. Whole ranges of hills, called "Downs," are

formed entirely of it. It is not only burnt for lime, but also, by a simple process, converted into "whitening."

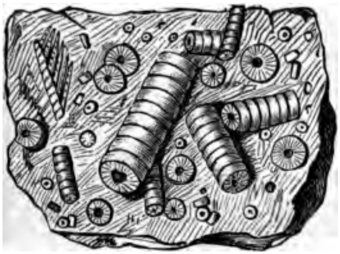
Round the windows and doorways of houses you may often see a bordering of stone, sometimes prettily sculptured. This is another kind of limestone. It is called "BATH-STONE," because it is quarried in the neighbourhood of that town. This stone is of a light yellow colour, and much used for building purposes. It is easily worked, being rather soft; only a little harder than chalk.

From Portland we obtain another limestone, called "PORTLAND-STONE." Convicts are employed in getting this stone. Convicts, you know, are men who have broken the laws of their country, and as a punishment they are sent to work in the quarries at Portland and elsewhere. Most of them are very bad men. They may be seen, with chains on their feet, wheeling the stone along, under the eyes of overseers, who, you may be sure, keep a strict watch over them. Portland-stone is not quite so light in colour as Bath-stone; it is rather grey. When burnt in a particular manner, and ground to powder, it is sold as Portland cement.

A very useful limestone, called "KENTISH-RAG," is found in the counties of Kent and Surrey. Some of it is burnt for lime, but most is used for building purposes. You have probably seen some very pretty churches built with a grey stone; the blocks are sometimes cut square, but often rather irregular in shape, with the outer part or surface

of each block left very rough, and protruding a little way. Well, this stone is Kentish-rag. When *in* the quarry, it is quite soft. I once went down a pit, and found the stone so soft that I could easily leave a mark with my finger nail.

The hardest kind of limestone is found in the centre and north of England. The sides of many mountains, such, for instance, as those of the Pennine Range, are composed of this hard stone It is called "MOUNTAIN LIMESTONE." This is the



PIECE OF LIMESTONE SHOWING THE CRINOIDS ON WEATHERED SURFACE.

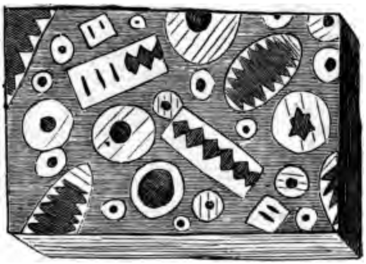
limestone of which you read, when in Standard III., as being mixed with the iron ore in the blast-furnace. It burns into capital lime, and is a good building stone as well.

There is another kind of hard limestone found in the north of England, which is called "MAGNESIAN LIMESTONE," because it contains, besides carbonate of lime, some carbonate of magnesia. Westminster Palace is built of it.

Whenever a limestone is hard enough to take *a polish, it is* called "MARBLE." Perhaps the

most beautiful is the white marble of Italy. It is interesting to know that this hard, handsome, crystalline stone is yet of precisely the same elementary composition as common chalk.

It is very easy to discover whether a stone is a limestone or not. Take a little bottle to the chemist's, and ask for a pennyworth of "spirits of salts." If the shopman should not understand this name, ask for "hydrochloric acid," for that is the chemist's name for it. If you have a piece of

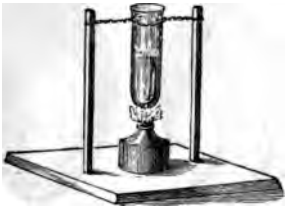


POLISHED PIECE OF LIMESTONE SHOWING THE CRINOIDS CUT ACROSS.

stone, and wish to ascertain whether or not it is a limestone, pour a drop or two of the acid upon it. Notice if there is a bubbling up. If there is, you may know you have a limestone. These little bubbles are the carbonic acid gas from the carbonate of lime. You can, if you choose, make a little carbonic acid gas, for experiment, in this way: —Place a few fragments of white marble in a test tube, pour on them some hydrochloric acid, and watch the result. In an instant there will be

such a bubbling up of the gas! You can test it by letting down into the tube a lighted taper, which is at once extinguished.

A little boy in the Third Standard saw his teacher doing this. The lad thought he would perform the experiment himself at home. So he obtained some marble, bought some acid and a test tube, and made a little apparatus, which he brought to the school. And besides making some carbonic acid gas, the little fellow made some oxygen as well. The lamp he used was very curious. It

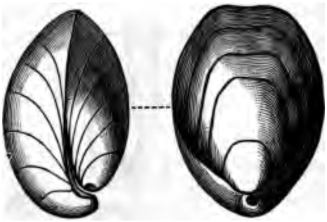


HOME-MADE APPARATUS.

was a small penny ink-bottle, into which he fitted a cork. Then he bent a little piece of tin into a short pipe, and stuck it through the cork for the wick to come through. The wick itself he made by twisting some worsted together. Here is a picture of the apparatus this little Third Standard boy constructed.

As you have read how clay and sandstone and slate are formed, perhaps you would like to know how all the limestone we get out of the quarries came to be there.

If any boy has been on Box Hill, or Brighton Downs, or on any of the other chalk hills of the South of England, surely he must have wondered where all that chalk came from. Many a man, as he is getting the hard limestone from the quarries of Derbyshire or Nottinghamshire, must, I think, stop now and again, and ask himself the question how all this limestone was originally formed. Well, this is not a very easy question to answer. But there are two or three facts about it that I will tell you, just to set you thinking.



FOSSIL LAMP SHELLS.

I have spent a good many hours working away in the chalk-pits of Kent, Surrey, and Sussex. And this is how I employed myself. When, after a long walk, I came to the pit, I first of all looked about for a large block of chalk to serve as a table. Then I went gathering odd lumps of chalk, and brought them to my "limestone bench." These I broke up with a hammer, to see if there was anything besides chalk. You will perhaps be astonished to hear that I found beautiful shells, something like large cockle shells, but having rows

of spikes on them. Also some pieces of white coral, showing the little spaces where once the coral animal lived. Once I found some sharks' teeth ; and at another time the shells of a very curious creature, that was able, whenever it chose, to stick up sharp spikes all over its body, like a hedge-hog, only much smaller, about the size of a hen's egg.

TOOTH OF EXTINCT SHARK (Chalk Series).

Now how did all these get here ? Sharks, you know, do not get up hills and drop out their teeth on such places as the North Downs.

Again, I once spent a whole day in a limestone quarry at Worthington, not far from Nottingham. The stone was quite crowded with shells, and with pieces of an animal that must have looked, when alive, something like a little tree-fern. There were corals also in abundance. Now all these are remains of creatures that must at one time have lived in the sea ! But Worthington quarry is in high ground, almost in the middle of England.

Well, it is of little use simply wondering about it. I must tell you, that all this limestone, whether hard or soft, was formed first of all on the bed of an ocean. Every particle of it is really the shell or some other part of an animal that lived, long ages ago, in the sea.

Now you understand one reason for placing the granite rocks and the limestones in two separate *classes.* The former have been formed mostly by

causes connected with the weather, while the latter have been slowly built up by living creatures.

There is one important rock, however, that cannot be placed in either of these groups; I mean coal. This has been formed entirely from vegetables; but we have described coal so fully in the First Science Reader, that it is not necessary to say more about it here.

Limestone is a carbonate of lime; that is, it consists of lime and carbonic acid. Most limestones have been formed in the sea by animals. The chief rocks of this class are Bath-stone, Portland-stone, Kentish-rag, chalk, and mountain limestone.

EXTERIOR OF BLAST FURNACE.

CHAPTER VII.

METALS—IRON.

Now that you have learned a little about elementary or simple bodies, such as carbon, oxygen, and hydrogen; and about such compounds as carbonic acid, silica, lime, and alumina, we shall be able to describe more fully than we have yet done the various operations connected with the working of metals. Also, our descriptions will be more interesting. You have already read a good many common facts about most of the metals. Now I am going to choose one of the most important of

them, and notice more particularly the chief points about it.

We will take iron. We do so for several reasons: First, it is not only the most abundant metal found in Britain, but also in the whole world. It is to be obtained almost everywhere. There is as much iron in our earth as of all the other metals put together.

It is like oxygen in one respect, for it combines with and forms a part of almost every known substance. It is in chalk and all other limestones. It is in clay, and slate, and coal. It forms a part of every plant. It is in *our* blood as well as that of other animals. Lastly, it is in nearly all our articles of food.

Certainly, iron and oxygen form a very large part of our world. It is remarkable that these two elements seem not only to have such a wonderful liking for other substances, but they also have a singular affection, so to speak, for each other. Hence the immense abundance of the compound "oxide of iron."

Although iron is found in union with so many other substances, it is only from a very few of these compounds that the metal is obtained. Iron is usually procured in the form of either a carbonate or an oxide of iron.

Nearly all the iron used in England is obtained from substances containing the carbonate of iron.

You remember we described the carbonate of lime as consisting of carbonic acid and lime. In like manner, carbonate of iron is carbonic acid

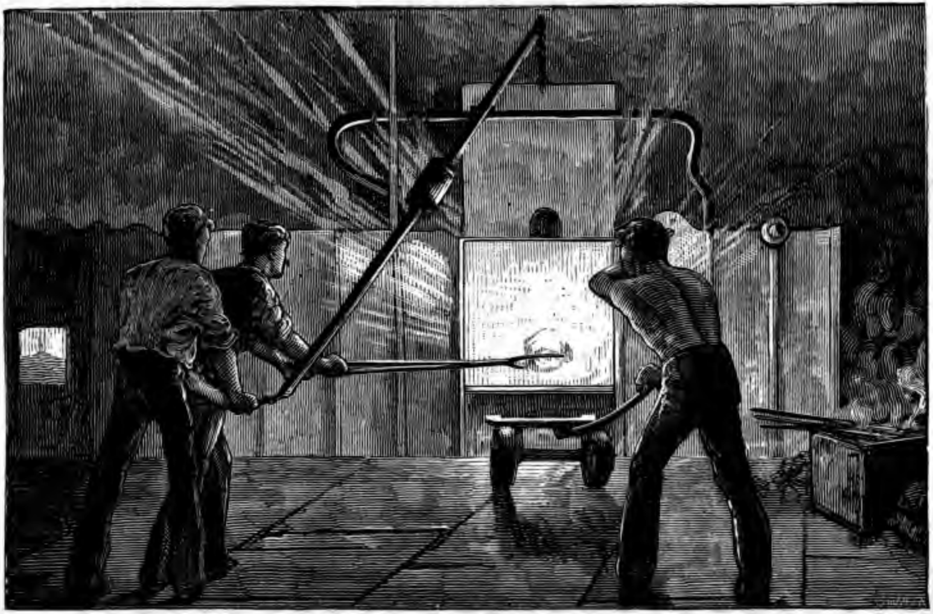
and iron. But we saw that lime itself is a compound formed by the combination of oxygen with calcium; so that carbonate of lime is really carbonate of the oxide of calcium; calcium being the name of what we may call the pure lime itself. Well, the carbonate of iron is really carbonic acid in union with the oxide of iron, and is therefore a carbonate of the oxide of iron; this latter being, as you have read, simply iron in combination with oxygen.

The two most important iron ores of Britain are "clay-band" and "black-band." These, you must understand, are rock masses, which contain, among other things, carbonate of iron. The work to be done is simply to get the pure metal out of these two ores.

For this purpose they are put into vast furnaces and melted, or "smelted." To do this intelligently, the smelter ought to know exactly what these two "bands" really are. He should know what they are composed of, or he will certainly be working in a sort of hap-hazard way.

Here the chemist comes on the scene to help the smelter. It is found by analysis that "clay-band" is composed mainly of these four substances:—(1) carbonate of iron, (2) silica, (3) alumina, and (4) lime.

Now, silica and alumina form, as you are aware, clay; hence the reason for this ore being called *clay-band*. *Black-band* consists of carbonate of *iron and a coaly* matter, which is, in fact, a sort



PUDDLING.

of impure coal; hence it has a darker appearance than the clay-band, and hence also its name. It contains no silica, no lime, and very little alumina.

We will now consider that we have these two ores from the iron mines, and proceed to describe the various means adopted for extracting the different forms of the pure metal.

In the first place, the ore has to be burnt, or as it is called, "ROASTED." This is generally done by piling the ore in heaps in the open air, and burning it with small coal. Sometimes it is burnt in "kilns." Second, the roasted ore is thrown into an enormous furnace, and "SMELTED." By this means the metal is obtained in the form of cast iron, which, as you know, is very brittle. Third, the cast iron is converted into wrought or malleable iron, by a process known as "PUDDLING." Fourth, the malleable iron may be made into the beautiful material we call "steel."

First, we will describe the *roasting*. Three or four hundred tons of clay-band and black-band are mixed with small coal and piled in heaps. Sometimes the black-band contains enough coal itself, without adding any more. A fire is then lighted at the windward side, and in four or five days the whole heap is burnt through; after which the fire gradually goes out, and the whole mass soon cools. During this burning, the carbonic acid from the carbonate of iron is driven off, leaving the oxide; just as in the lime-kilns the carbonic acid *is expelled and* the lime remains. A quantity of

sulphur also, and of carbon are burnt out of the ore. We have now, in the heap, a much larger proportion of iron than before the roasting. In fact, two-thirds of the heap is the pure metal, whereas previous to roasting there was only one-third.

The next process is *smelting*. The roasted ore is thrown into a great furnace, where the heat is so intense that the iron is melted and sinks down to the bottom in a liquid state. I daresay you have often thrown a piece of dirty lead into the kitchen fire, and watched the clean, bright metal run out beneath, among the cinders.

A long while ago, wood was used to make up the fire, but now coal or coke is employed. It is found, however, that if only the ore and coal are thrown into the furnace, there is a great waste of iron; the explanation of which is easy enough.

The roasted ore consists mainly of three substances,—oxide of iron, silica, and alumina. Now if those were melted together, the silica would unite with a portion of the oxide of iron, and form silicate of iron. This would float on the surface of the liquid iron as a sort of scum, and have to be drawn off and cast on one side as being comparatively useless. The smelter would therefore, in such a case, not get all the iron from his ore, but only just so much of it as the silica was unable to combine with.

This, you may be sure, no smelter would allow;

for his aim is to obtain if possible every particle of metal from the ore.

What then is done? I will tell you. Something is thrown in along with the ore, that will combine with the silica and alumina, and so set the iron free.

There are several substances which will effect this; such as the carbonates of soda and magnesia, borax, and limestone. Of these, limestone is the most abundant and most easily obtained, and is therefore the material employed.

It is the hard mountain limestone that is used, for it is always found in the same locality as the iron ore and the coal.

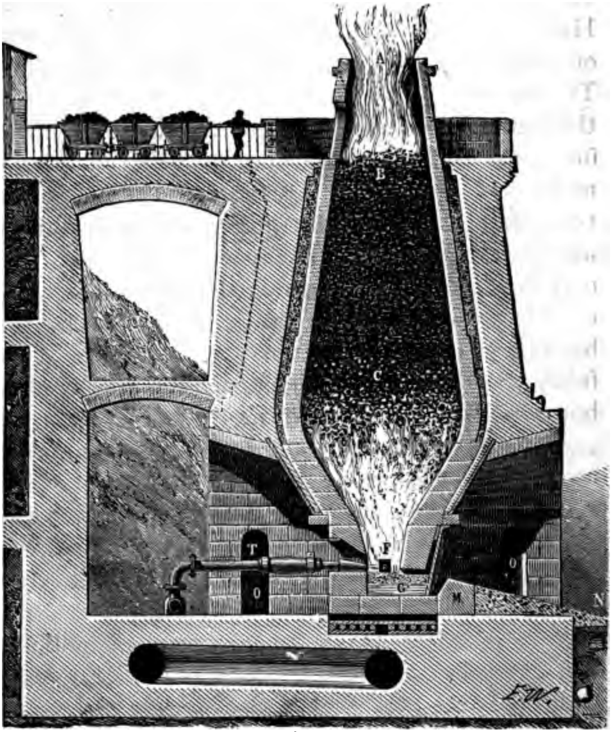
What a fortunate circumstance for the smelter that all his materials are so close at hand! I have even heard that all three are sometimes obtained from the same pit!

Formerly, the limestone was first burnt and the lime used; but you can easily see that this was very unnecessary work, for the heat of the furnace very soon converts the limestone to a lime.

It is found that the lime not only combines with the silica and so prevents the formation of silicate of iron, but that it also causes the whole to melt at a much less heat. Here, then, we see that the lime effects a saving of coal. We also learn why the lime is called a "FLUX."

Three different substances, therefore, are thrown into the furnace,—roasted ore, coal, and limestone. These are first mixed up roughly in the open field,

where they stand in heaps ready to be wheeled in barrows and pitched into the top of the furnace.



SECTION OF BLAST FURNACE.

Generally speaking, the following materials go to make up a heap:—

Roasted black-band .	4½ cwt.	Limestone . .	2 cwt.
Roasted clay-band .	4½ ,,	Coal	10 ,,

We must now describe in a few words the furnace. At the head of this chapter is a view of the exterior of one; but we want to see what the inside is like. Here is a drawing of the interior of a blast-furnace, of which the height is from forty to fifty feet. The furnace-man brings the ore in trucks along the gallery at the top, and throws it into the furnace through an opening at B. The melted metal sinks down from B, through the great furnace, to the hearth G, from which it is from time to time allowed to run out over the slab M into channels made in sand at N in front of the furnace. At F you may see one of the openings for the hot-blast pipe T; for I must tell you that these furnaces are kept at their proper heat by very hot air being blown on to the fire.

The iron which is obtained from the smelting furnace is cast-iron. It is usually called pig-iron, and contains a certain amount of carbon.

The most abundant metal in the world is iron. The chief iron ores are the carbonates and oxides of iron. Most of the iron smelted in England is obtained from the carbonate of iron; which is found in two important ironstones, called clay-band and black-band.

WINDMILL.

CHAPTER VIII.

FORCE, WORK, AND MACHINES.

IN Chapter IV. something was said about the act of making a point to a stick of chalk by scraping one end of it. Do you remember, we asked ourselves three questions respecting this? We wished to know, first, why the particles came off the stick; second, why they fell to the ground when they *did* come off; and third, what held them on to the stick *before* they came off. The third question we have already answered. The second must be left for another time. We will try now and give a good answer to the first.

What causes the particles to come off the stick of chalk? Doubtless most boys would answer, "The knife." Others might say, "The knife could not sharpen the chalk by itself, it was the strength *of the teacher's* arm that moved the knife." And, *again, some* would be inclined to think that the

strength of arm, however great, would not serve the purpose without the knife, or something similar.

It is clear that in this simple act there are three things to be considered—(1) The strength of arm which moves the knife; (2) The knife itself; and (3) The coming off of the particles of chalk. We will call No. 3 the work done.

Let us try and ascertain whether, in the case of any work being accomplished, there is anything which we may well compare with Numbers 1 and 2.

Near this school, some men are engaged building a house. One man is getting up baskets of bricks to the top scaffolding. Here, then, is work being done. He hooks on to the basket one end of a rope, which passes over an iron pulley at the top of the house. Then, by pulling at the other end of the rope, he raises the bricks. In this case it is evident that the pulley and the rope correspond with the knife in our first act.

Again, a train is at full speed, and work is being done. It is, you know, just as much "work" as if men were pushing it along. Here, the engine answers to the knife or the pulley, and the expansive force of steam corresponds with the muscular strength in the examples just quoted.

We will take another instance of work being accomplished. The wind blowing against the sails of a windmill, sets some machinery in motion, and the *work* of grinding corn is the result.

In all the examples we have named, there is a

certain likeness. We find "force" setting something or other in motion. Muscular force moves the knife and the rope passing over the pulley; the expansive force of steam moves the locomotive; the force of wind moves the windmill; and we may add yet another instance, and say, the force of the running mountain torrent moves the water-wheel. Also, in all these examples, work is performed.

The exact position occupied by the knife, the pulley, the engine, the windmill, and the water-mill, is simply that of connecting the force applied with the work to be accomplished.

These instruments or machines take up the force as it were, and pass it on. For instance, the sails of the windmill take up the force of the wind, and pass it on to the machinery in the mill; this machinery passes it on to the great grinding stones; and, what is more, these grinding stones pass it on somewhere else, but in a different form. For the stones and the grains of wheat become hot, and heat the air around them. Now heat is really a "force;" so that force is continually "passed on;" none of it is really destroyed. You read in Chapter IV. that matter is indestructible; so is force. This, however, we shall more fully describe by-and-by.

If you look at any piece of machinery, say a locomotive engine, you will soon discover that it consists of many parts. There are wheels of various sizes and patterns, and iron rods of

different thicknesses and shapes. It is the same with a cotton mill or the works of a clock. And yet although there seems to be such a confusion of parts, it is possible to arrange them all into what we may call elements of machinery ; just as we may separate compounds into *their* elements.

We shall find that all, even the most complicated machinery, consists of a very few, only three or four, elementary parts, which are termed "mechanical powers," or "simple machines."

Often these elementary parts may be used singly. We will give an instance of one. A man wishes to raise a large block of stone a few inches. He may grasp the stone firmly in his arms, and exert all the strength he has, and yet be quite unable to move it a single inch. But he gets an iron rod or crowbar, puts one end of it beneath the block, places a little piece of iron or wood under the rod close up to the stone, then presses down the other end of the rod, and so raises the great block easily. In this case he has used one of those elementary parts of machinery called "a lever." The most important of all the mechanical powers is the lever.

I want you to clearly understand the part played by the lever in this operation. Some work is to be accomplished. The force at hand is the muscular force of the man. If this force be applied direct, that is with nothing connecting it with the work, it is insufficient to raise the stone. But if a lever be used, so that there shall

be an indirect application of force, then the block is easily raised. Now we may well ask, "How is this?" There is no force in the lever itself; neither can it make or create force. No machine can do this. All that it can possibly do is to pass on just so much force as is applied to it. If this is so, how comes it that so much seems to be gained by using a lever? This question shall be fully answered another time. All I am anxious for you to understand at present is, that force is seldom applied direct; that some contrivance intervenes; and that such contrivance, whatever it is, is called a machine.

I do not mean to say it is impossible to apply force in a direct manner. I was once giving a lesson to some boys on this subject, and showing how the expansive force of steam was used to raise great boxes of gravel from a deep pit. I explained that in this case the force was applied indirectly. It drove an engine, which, by means of wheels and levers, raised the gravel. All at once a little fellow in the class jumped up and said *he* knew how the force might be applied direct, that is, with nothing coming between. I asked him to explain. He said we might put the boiler down the pit under a box of gravel, then make up such a great fire that the boiler would burst and blow the box and the gravel and everything else to the top very soon. Another boy in the class said "that would not do;" and we all agreed that, although this would certainly be

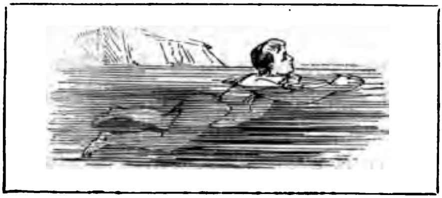
applying the expansive force of steam in a direct manner, yet it would be very inconvenient.

There are other mechanical powers besides the lever. There is the pulley, which we have already noticed.

You have probably seen three or four men getting a great hogshead of sugar up a step into a grocer's shop. If so, you must have noticed that they placed a plank with one end on the step and the other on the pavement. They then easily rolled the barrel up the plank into the shop. Very likely these men could not, with their utmost strength, have lifted the hogshead up the step. This contrivance is called the inclined plane.

We shall, however, have more to say upon the subject of the mechanical powers when you get into Standard V.

Work of any kind results from the application of force. There are many kinds of force. There is the muscular force of man and of the other animals; the expansive force of steam; the force of wind and of running water, and many others. A machine conveniently connects the force applied with the work to be done. Force, like matter, is indestructible.



SWIMMING.

CHAPTER IX.

THE AIR IN WHICH WE LIVE.

It is a capital thing to be able to swim. How enjoyable, on a hot July day, to feel oneself borne up and down on the waves of the sea! Any one swimming about like this, with his head just out of the water and his body in it, is really in a very curious position. He is at the top of one ocean and at the bottom of another. There is the ocean of air above, and the ocean of water below. In some respects these two oceans are alike, in others different.

The ocean of air is one great continuous covering spread all over the earth; but the ocean of water is broken up by the land into several portions. The ocean of water is nowhere more than ten miles deep, but the ocean of air is at least two hundred miles from bottom to top.

Animals and plants live in both. But in the *ocean of air* they live in the lowest part, while in *the ocean of* water they are found mostly in the *upper part.* No bird or any other animal could

live, at a height of eight miles or so, in its air-ocean; and no fish could live at a depth of eight miles in its water-ocean.

There is, at least, one respect in which these two oceans are exactly alike. They are never still. Air from one place is always rushing on to some other place, producing currents which we call "wind." In like manner, water from one part is always flowing away to some other part, causing what are called "ocean currents."

Quite recently, it has been found that there is another point of resemblance. The warmest parts of these two oceans are just where they touch each other. From that part they each become colder and colder the farther we go; the higher we mount into the air, or the deeper we dive into the ocean, the colder it is. At a depth of four or five miles in the sea, it is as cold as ice; and at the same height in the air it is just as cold.

There is yet another comparison to be made. When we and other air-ocean animals breathe, it is the oxygen of the air we really *want*, and must really *have*, or we die. Similarly, when fish and other water-ocean animals breathe, it is the oxygen of their ocean they want, and must have, or they also die. But notice the difference here. We, by breathing in their ocean, could not get at the oxygen; neither could they by breathing ours.

It has already been explained that oxygen and nitrogen are the two gases which form the air. You have read about this in Chapter II. You

will remember, we described an experiment which proved that one-fifth of the air was oxygen, and the remaining four-fifths nitrogen. But there are other bodies present besides these. There is a gas called "ozone," another gas called "ammonia," besides "carbonic acid gas" and a large quantity of "watery vapour."

Now I want you to understand clearly what this aqueous vapour really is; because its presence in the air is the cause of a vast number of things we see happening every day of our lives.

First of all, we had better make quite sure that there *is* water in the air. If a tumbler of very cold water be brought into a warm room, it will very soon be found that the outside of the glass has become dull and steamy. If we pass our finger over it, we see that this steamy appearance is due to the presence of vast numbers of little spots of water. Now how did this water come on the glass? It could not have passed through from the inside. No, it came from the air. Therefore water is in the air, although we may not be able to see it.

You remember that when we were inquiring into the nature of oxygen, we made some of the gas, and then examined its properties; and the same with carbonic acid gas, and other things.

Well, we had better follow a similar plan with respect to vapour. Let us make some water-vapour, and then try and discover its character. I know that every time the water boils for breakfast

or tea we can see the cloud of steam rushing from the spout of the kettle, and we might learn a great deal about water-vapour from that; but we must have something that we can place upon the table and examine more conveniently than we could the kettle.

It will be necessary to have an oil-flask half-full of water. We must then fit a cork to it, and bore a hole through the cork to receive a glass tube, bent at right angles, and pointed at one end.

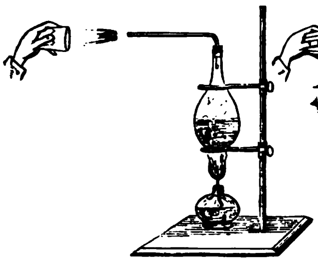


FIG 1.

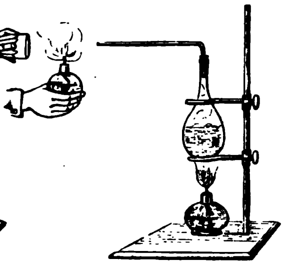


FIG 2.

Two spirit lamps, a stand, and a large tumbler, will complete the apparatus.

Light one of the lamps, place it under the flask, and then watch. In a minute or two the water will boil, and a cloud of steam will rush out of the pointed end of the glass tube. The picture, Fig. 1, shows exactly what happens.

If the tumbler be held so that the jet of steam shall beat into it, the inside of the glass will become quite wet, and a tea-spoon full of water

may be collected. This white cloud, that people call steam, is really a countless number of tiny globes of water. You will observe that close up to the point of the tube, nothing is seen. The white cloud begins at about a half-inch from this point. Also you notice that in the flask itself there is no white cloud ; the space is quite clear.

Now light the second lamp, and hold it just under the point where the steam begins to be visible; as you see in Fig. 2. A remarkable result follows. The white cloud has completely vanished! Remove the lamp, and the steam re-appears. Replace the lamp, and when you have caused the cloud to disappear, hold the tumbler in exactly the same position as before. Now, although we see nothing entering, yet the inside of the glass becomes nearly as wet as when we held it full in the cloud of steam. It is evident, therefore, that we have water here, in some form or other, in the air, and that it is invisible.

Let us now blow out the two lamps, place the tumbler on the table, and ask ourselves a few questions as to the meaning of what has been done.

In the first place, it appears that water may be present in the air in two different conditions—visible as a white cloud, and invisible. Second, that heat causes water to pass into the air and become invisible. And third, that a cold glass *causes this invisible water to form into liquid visible water.* We will now agree upon the use

of certain words to express all these things. The white cloud, which I have just told you is simply a multitude of little globes of clear water, we will call "steam." This is the common use of the word, and we will keep to it.

The invisible water, such as that contained in the clear part of the flask, and to which the heat of the lamp changed the steam, we will term "vapour."

The conversion of the water in the flask to vapour, by the heat of the lamp, we will call "evaporation."

Lastly, the deposit of vapour, in the form of water, upon the inside of the tumbler is "condensation."

Now that we have certain words to which we have attached definite meanings, we shall be able to state clearly our ideas about the experiment we have performed.

In Fig. 1, the heat of the lamp evaporates the water. The vapour rises in the flask, passes through the bent tube, and almost as soon as it gets into the air, is condensed into steam.

In Fig. 2, the heat of the second lamp prevents the condensation of the vapour in the air; or, in other words, enables the water to remain in the invisible condition; although its presence is proved by its wetting the inside of a tumbler.

And now it is time we put our string of questions. First, what causes the water in the

flask to be converted into vapour? The answer is "heat." Probably some inquisitive boy would like to ask, "How, or why, does heat cause water to evaporate?" A very good question, but one that it is impossible to answer until we have a clear idea of what heat really is; which is not the case at present. All we can say now is, that "heat," as we commonly understand it, causes water to evaporate.

Question No. 2, How is it that as soon as the vapour comes into the air, it becomes condensed into a cloud of steam? We answer, the cold air causes the condensation. We conclude that it is "cold" that causes it, because we have seen that "heat" prevents it.

Question No. 3, If steam is nothing else but a number of little globes of clear water, why is it white? for clear water is not white. To answer this question, I must call your attention to one or two other cases where a similar effect is seen.

Clear glass, you know, is not white; yet if you hammer a piece of such glass into very small pieces, you will have a white powder. Ice, as you are aware, is clear and colourless, and yet snow, which is simply ice in fine division, is the whitest thing we know of. I have been on the deck of a ship when the great blue waves have risen and dashed all over us in a cloud of white spray. In these instances, as well as in the case of steam, the whiteness is due to the way the light shines upon the little transparent particles.

here is yet another question to ask, How is ıat the cloud of steam seems to come to .ing, or to disappear of itself, at a distance of ıt two feet from the tube, even without holding lamp to it? In other words, what is it that ›orates this steam? You will very likely ›er, "It is the heat of the air that does this." do you not think it very strange, that the e air which is cold enough to condense the ›ur as soon as it leaves the tube, is, at the e time, warm enough to re-evaporate the m at a distance of two feet? This is a fact iring some explanation. We know it *is* a because we see a similar thing happen every day of our lives. On a frosty morning, we the out clouds of steam, and at a distance of ›ot or two from our mouths, that steam is ›orated, or becomes invisible vapour.

'he *complete* explanation of this we must leave l you understand the nature of heat. You v, however, that the heat *inside* the flask is ter than that *outside*. You are also aware, ı the rush of steam at the tube, that the ›ur inside is trying very hard to get out. ; means that the vapour is pressing very h against the inner surface of the flask; which he same as saying that this inner surface ses very much against the vapour. This being case, the vapour is compressed, or squeezed a space much smaller than it would occupy e *from* pressure. Hence there is a great

deal of vapour in a very small space. But there is quite enough heat in this little space to keep all this vapour from condensing.

When, however, the vapour enters the air, and before it has had time to spread out, there is not enough heat to keep it in the vapour-state; so it condenses into that cloud of water-dust we call steam. Now when, at a distance of a foot or two from the tube, the steam has spread itself out, then there *is* sufficient warmth in the air to reconvert it into invisible vapour.

As I said before, this is not the full explanation, but it is some way towards it.

The air contains among other things, a large quantity of water, which, when invisible, is termed "aqueous vapour," or simply "vapour." Water is converted into vapour by heat. "Steam," as commonly understood, is not really vapour. It is water in fine division, and results from the condensation of vapour by cold.

SCALES, SHOWING HOW IT IS POSSIBLE TO WEIGH A VESSEL CONTAINING AIR.

CHAPTER X.

THE THERMOMETER AND BAROMETER.

BEFORE proceeding further with our description of the atmosphere, it will be necessary to explain the nature of two very useful instruments—the "Thermometer" and the "Barometer."

We have seen that the warmer the air is, the greater the quantity of vapour it is capable of holding. But we should like to be able to state exactly *how* warm or *how* cold the air is; for merely to say some air is warm and other cold, gives us no information as to how much warmth there is in one, or how little there is in the other. If, for instance, you brought me two loaves of bread of different sizes, and asked me to tell you *their weights*, it would be useless my saying one

is "heavy" and the other "light." You would wish to know *how* heavy, or *how* light; and to answer such questions, we must have a measure of weight. As you know well enough, we have such a measure. We express the weight of any substance in such terms as "pound," "ounce," "ton," etc. A pair of scales is the instrument generally employed to ascertain or indicate weight.

THERMOMETER.

In like manner we express temperature in terms of "degrees;" and the instrument employed to ascertain degrees of temperature is the "Thermometer."

You have probably seen one of these. A closed glass tube, with a bulb at the lower end, is partly filled with mercury, and fitted into a box-wood frame. Heat, you have learned, expands metals. Therefore the mercury in the tube will rise or sink just as the air around it is either warm or cold. The greater the heat of the air, the higher the mercury rises. If now we mark on the box-wood frame, just by the side of the tube, a scale of equal distances, we shall be able to measure the exact height to which the mercury rises, or *the distance to* which it sinks.

But it is quite clear that such a scale would

also measure the various degrees of temperature which have caused this rise and fall.

Hence the thermometer, which shows us the expansibility of mercury by heat, comes to be an instrument for measuring heat itself.

I am not about to explain to you the various ways of marking the degrees on thermometers; that we will leave for the present. But on all ordinary thermometers, the temperature at which water just begins to freeze is marked as 32°. Hence 32° is called the freezing point of water. When, therefore, the mercury in the tube sinks to this point of the scale, it shows that the air is just cold enough to freeze water. On an ordinary summer's day, the mercury stands at about 65°. The heat of the human body, when in health, is about 98°. The heat of boiling water is 212°; and so on.

But besides being "warm" or "cold," the air is also "heavy" or "light;" in other words, it has "weight," like all other material things.

Every object that has weight, is also capable of exerting "pressure." For instance, I support a book on the palm of my hand. The book has weight, and I feel that it exerts a pressure on my hand; the pressure being simply the tendency of the book to fall to the ground. Any one can see clearly enough that solids and liquids have weight; but it is not so readily seen that the *air* has either weight or pressure. A very simple experiment will, however, soon prove to you that our atmosphere *does* exert pressure.

Fill a tumbler to the brim with water, and cover with a piece of card in such a way that the card is in contact with the water. You may now invert the glass, and the water will not run out. Now, as water is matter, and so has a tendency to fall to the earth, there can be but one reason for its not so falling. It is this. Something must be pressing the card upwards with a force at least equal to the weight of the water. But there *is* nothing on the outer surface of the card but air. Therefore it is air which is pressing upwards against the card and preventing the water from falling.

But if the tumbler be held sideways, or in any position, the water still remains in it. Hence we conclude, that not only does the air exert pressure, but it does so in every direction.

This being the case, we have two or three questions to ask ourselves: First, "What is the amount of this air-pressure?" Second, "Is it the same everywhere, and at all times?" Third, "If it is not the same, what is it that causes the difference?" And, Fourth, "Have we any contrivance or instrument for showing the differences in air-pressure, or of measuring the *amount* of the pressure?"

Let us see how far we can answer some of these questions. You know very well that there is a vast ocean of air surrounding our earth, and extending to a very great height. You also know *that this* air, being matter, has weight. It must,

therefore, be very clear to every boy here, that the air near the earth, or at the bottom of this air-ocean, must be pressed upon by all the air above.

For example, if I pile thirty or forty sheets of wool one above the other, the lower sheets will be under the pressure of the upper ones. If I thrust my finger in between any two of the lower sheets, I shall feel the wool pressing against it with a greater weight than if I did the same between the upper sheets.

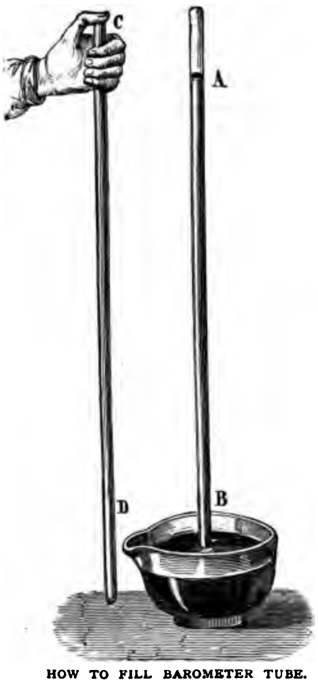
It is precisely the same with the air, and for the same reason. The air *near* the earth exerts a far greater pressure upon objects than it does at a *distance* from the earth. The higher we ascend into the atmosphere, the less is the pressure.

We may observe another fact about our sheets of wool. The lower ones are compressed by the weight of those above. In other words, the very little fibres or threads, of which the wool is composed, are, in the lower sheets, squeezed closer together than they are in the upper ones.

Here, again, it is exactly similar in the case of the air. The tiny atoms of oxygen and of nitrogen, and of the other things which make up the air, are in that part of it near the earth compressed or squeezed close together by the weight of the air above. Hence we say, that near the earth the air is "dense;" but as we ascend higher and higher, we meet with air less and less dense, and we say such air is "rare."

In order to show how the pressure of the

atmosphere is indicated and measured, we will return to our experiment with the tumbler of water and the card. Upon inverting the glass, it is evident that there are two things pressing against the card. There is the water above, and the air below. So long as the pressure from below is greater than that from above, the water will remain in the inverted tumbler. But if we have a glass so deep that the quantity of water it will hold is sufficient to exert a pressure greater than that of the pressure of the air, then it is evident the card will fall away and the water run out.



HOW TO FILL BAROMETER TUBE.

The question to be answered, therefore, is, what is the greatest weight of water the pressure of the atmosphere will support? You will perhaps be astonished when I tell you that to answer this question by means of an experiment, we should be obliged to procure a tube over thirty feet long. Such a tube would be very

inconvenient to handle. We are not, however, limited to the use of water in our experiment.

Suppose we endeavour to find how much of some other liquid, heavier than water, the pressure of the air will support. Let us take mercury. If we get a glass tube of about thirty-four inches long, whose bore is one square inch, and close it at one end, we may easily fill such a tube with mercury. Placing our fingers upon the open end of this tube we may just allow it to dip into a little saucer of mercury, and then remove our fingers. We shall find that the metal will sink three or four inches from the top of the tube, but no more. This quantity of mercury must therefore be kept up in the tube simply by the pressure of the air. Such a volume of mercury weighs exactly 15 lb.

BAROMETER.

Therefore the conclusion at which we arrive is this, that the pressure of the atmosphere is equal to 15 lb. on every square inch. The higher we ascend, the less is this pressure. It also varies day by day; but all the causes which lead to *these* variations are too difficult for you to understand at present.

The instrument by which the pressure of the air is measured, is the "Barometer" and is simply a glass tube of about thirty-four inches long, closed at the top, but open at its lower end. The rise and fall of the mercury in this tube, indicates a

corresponding increase or decrease in the pressure of the atmosphere.

The Thermometer is an instrument for indicating variations in temperature. Its action depends upon the fact that bodies are expanded by heat. The Barometer is an instrument for indicating variations in the pressure of the atmosphere. Its action depends upon the circumstance that variations in the height of a column of mercury show corresponding variations in the pressure of the air which supports such a column.

MORNING.

CHAPTER XI.

DEW—CLOUDS—HAIL—RAIN—SNOW.

In early spring or late autumn, we often have beautiful, bright, warm days, followed by very cold, misty, damp nights. *Golden* days, and *iron* nights, we might well term them. During one of these days, the atmosphere will be full of vapour. But after the sun has set, the ground quickly cools, *and the air* near it is chilled. The vapour of the *air thus chilled*, condenses, and becomes visible as

a mist or steam; this is deposited during the night, in the form of little globes of water, upon every leaf and twig; in fact, upon all objects that have given up the heat they received from the day's sun. This is dew.

You will often hear people talk of the "dew rising" or "falling." Neither of these phrases is quite correct. It is better to say the dew "forms."

If we are out early on some fine autumn morning, we shall find, that as the sun rises, the crystal globes of dew gradually disappear. They have all evaporated. The heat of the sun has changed them to invisible vapour, which, being lighter than air, rises. But, in its upward journey, it soon meets with a cooler air; here it condenses, and becomes visible as one of those early morning clouds we often see form in an otherwise clear blue sky. The sun, however, rises higher and higher, and by-and-by warms this upper air also. Then the steam-cloud re-evaporates, and takes another step upwards. And now, at a greater height than before, this vapour, meeting with a colder air, is again condensed, and becomes a cloud. But the still-rising sun strikes with increased heat upon this cloud also, and re-converts it to vapour.

Thus, you see, our early morning dew is lifted up, as it were, step by step by the grand old sun, as he rises higher and higher. And this same wonderful sun-work is continually going on, not *only in the case* of the dew, but of all the water *on the surface of* the earth. Hence the whole of

at least the lower part of the atmosphere is filled with vapour. High above us, however, the air is cool, and so the upper part of this vapour is condensed, and forms clouds.

Have you ever observed that clouds are frequently lumpy, or in rounded masses on the upper side, while they are comparatively straight on their under side, something like this picture?

FORMATION OF A CLOUD.

Such a cloud is really the summit or cap of a great mass of vapour extending to the ground; the upper part of which, at this height, has condensed by the coolness of the air. A straight line drawn from A to B, would mark the height at which the warmth of the atmosphere is no longer sufficient to maintain water in a state of vapour.

If anything should occur to suddenly chill the air below A, B, the vapour would condense so

quickly as to form drops of water, which would fall as rain. It is very easy to see that many things might happen to produce this result. For instance, a great body of warm air, with its load of vapour, might, in moving along over the surface of the earth, meet with a lofty mountain whose summit was covered with snow. Here a great condensation would at once take place.

Or a mass of cold air might blow into a mass of warm air; in which case the latter would be chilled and its vapour condensed. Such a result as this can easily be proved arithmetically.

Two facts, however, require stating before we proceed to the proof: First, it is found that air of a certain temperature will hold only a definite quantity of vapour, and no more. Second, that if a body of air be raised 20° in temperature, it will hold double as much vapour as it held before.

With these two truths before us, let us suppose we have five separate volumes of the atmosphere at different degrees of warmth. Say we have one volume of air at 30°, another at 50°, a third at 70°, a fourth at 90°, and a fifth at 110°. There is, you notice, a difference of 20° between each; consequently each volume of air would hold double as much vapour as the next to it lower in temperature.

(1)	(2)	(3)	(4)	(5)
30°	50°	70°	90°	110°
10 lb.	20 lb.	40 lb.	80 lb.	160 lb.

We will suppose volume No. 1, namely that at 30°, to contain 10 lb. of vapour; then No. 2 would contain 20 lb.; No. 3, 40 lb.; and so on.

Let us now imagine that a strong wind blows, and that some of these various bodies of air become mixed together. For instance, suppose Vols. (2), (3), and (4), to mingle in one great volume. The temperature of this great body of air would be 70°; because 70 is the average of 50, 70, and 90. We consequently have three volumes of air at 70°. But one such volume will contain 40 lb. of vapour. Therefore any boy can easily see that three such volumes would hold 3 times 40, or 120 lb., and no more. Well, but the volume at 90° brought 80 lb.; that at 70° brought 40 lb.; and that at 50° brought 20 lb.; in all, 140 lb. of vapour. This is 20 lb. more than the entire volume will hold. What, therefore, becomes of this 20 lb.? It is, I am sure, clear enough to you all that it must "get out" in some way or other. As a matter of fact, it gets "squeezed out." In other words, it condenses and falls as rain. Hence it appears that rain may result from the chilling of a body of warm air through the inrush of cold air.

I have just made use of the expression "squeezed out" as equivalent to "condensed." You will very likely consider this a queer phrase. It can, however, be shown to be a very good one. We have already seen that in dense air the atoms

are closer together than in rare air ; and heat will cause dense air to become rare,—a fact which any boy may easily prove. Get a paper flour-bag, half-fill it with air, tie up its opening, and hold it in front of the fire. You will observe the bag swell up and become quite full ; not a wrinkle will be seen. But if you remove it to a cold place, the bag will shrivel up, and appear only half full, as before. Why is this ? It is because the heat has driven the atoms of air farther apart, so that it takes up more room.

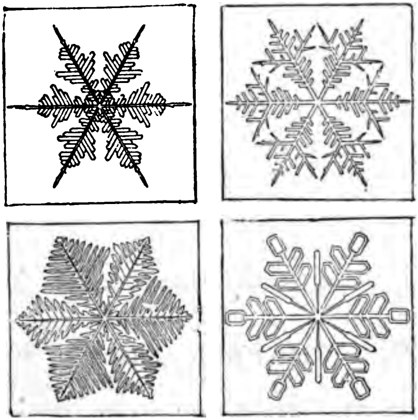
Now when vapour is in the air, the extremely small vapour-atoms fill the spaces between the air-atoms. If the air is warm, these spaces are large, and so a great many vapour-atoms can find room in them. But if that warm air is chilled, and its atoms go closer together, what do you think must happen to the vapour-atoms ? You will at once answer, "They must be forced out, of course." Well, a good many vapour-atoms thus "squeezed out" unite to form the smallest possible particle of water ; and a good many of these particles unite to form a drop of rain ; and, as you know, a good many drops form a shower.

We will now, for a moment or two, return to our early morning dew.

If the night has been frosty, all the tiny globes of dew become frozen into the most beautiful crystals of ice, and hoar-frost is the result.

When the sun rises, its heat melts this ice, then *changes the* water to vapour, and, as we have seen

causes it to mount higher and higher in the air. Very possibly it will rise so high as to meet with air below 32° in temperature. In such a case, the vapour not only condenses to steam, but the tiny globes of water, of which the steam-cloud consists, are frozen to snow, so light and fleecy that it does



not fall to the ground, but remains high in the air as thin and feathery clouds. Sometimes, however, several of these minute particles of ice which form the snow-cloud, unite into a little flake or pellet of snow. Such flakes may be too heavy for the air to bear up, so they fall; and in their passage downwards, become enveloped in coatings of ice, and we have a shower of hail. You will remember reading of this in Standard III.

Snow is formed whenever the air, out of which

the vapour condenses, is so cold that the little globes of water are frozen into ice-crystals. A snow-flake is simply a group of such crystals adhering to one another.

Dew is the result of the condensation of the vapour of the air by the coolness of the earth after sun-set. Clouds and rain result from the condensation of air-vapour by the coolness of the air itself. Snow is frozen rain. Hail is formed by the coating with ice of tiny snow-flakes that have fallen from lofty snow-clouds.

CHAPTER XII.

THE VEGETABLE KINGDOM—PARTS OF A PLANT.

In the "Third Standard Reader," you will perhaps remember, we classified all the objects of nature under two heads—animate and inanimate. The former includes everything that lives, and consequently embraces the whole vegetable and animal kingdoms. A plant, or an animal, during its life, passes through certain stages; it is born, receives food into itself, grows, produces other objects like itself, and then dies. For instance, a *plant is* born in a seed, grows by taking food from

VIEW IN TROPICAL FOREST.

the ground or from the air, produces seeds, which become plants like itself, and sooner or later dies. An animal, in like manner, passes through similar stages. At present we will say nothing respecting the life and growth of an animal; we will confine our attention to plants.

In order that the plant may grow, feed, and produce seeds, we find it provided with certain parts or "organs," such as root, leaves, and flowers. Each of these has a special duty to perform, called its "function." Thus, the function of the root is to absorb food materials from the ground. The function of the flower is the formation of seeds.

In this chapter we are going to describe some of the organs of a plant, and the functions of those organs. For this purpose we will select three plants, which every one may easily obtain—the buttercup, the wall-flower, and the primrose. It will be well for each of you to get these three, and find out for yourselves the parts of which we shall speak.

Should you be looking about in the fields for a buttercup,—of course I do not mean the yellow flower only, but the entire plant,—you will soon discover that there are three or four different kinds. The one I want you to get is a little, compact, bushy plant, with beautifully shaped leaves, each leaf divided into three distinct parts. Besides this, it has a sort of swelling or bulb just *above the root*, and only one flower on each *flower-stalk*. Don't get one of those straggling

plants, with very long flower-stalks, and leaves cut into small, narrow segments. If you have obtained the plant I am about to describe, and which goes by the name of "bulbous buttercup," you must wash all the dirt from the root, and carefully spread out the whole plant on a sheet of clean paper.

Then you must have a little wall-flower plant. Here, again, do not choose a large, straggling one, with many branches, but a nice, compact plant, with just one upright stem around which the leaves grow, and on the summit of which is a head of flowers. Wash the root of this also, and spread it out on a sheet of clean paper.

Then try and procure a common primrose; the entire plant, of course. Wash the root, and spread out, as in the other cases.

I will suppose we have these three plants before us, and are anxious to learn all we can about them.

First, we will examine and compare the roots. As you read in the "First Science Book," this fixes the plant to the earth, and also absorbs from the ground certain substances which form its food. When the plant was very young, there was but one shoot or thread which constituted the root; but gradually this solitary thread sent out branches. In all three of our specimens, the root really consists of a bunch of such threads; they are called "fibres." The food materials do not enter those fibres over their entire surface, but only at their

extreme ends, where there is a group of special minute sacs or "cells." In nearly every part of a plant, cells are found; but it is only those groups at the extremities of the root fibres that have the wonderful power of drawing or absorbing from the ground the substances necessary to build up the plant. Such a group of cells is called a "spongiole." I will give you a list of some of the minerals these spongioles absorb—lime, flint, sulphur, phosphorus, soda, iodine, and ammonia.

You will, I am sure, wonder how it is possible for such substances as lime or sulphur to enter the tiny threads of the roots of plants. I must, therefore, tell you that all these things must be in such a form that they will dissolve in water just like sugar or salt dissolves; not simply mix with water, like chalk, which, after a little while, all settles to the bottom.

In the root of the wall-flower, you notice there is a rather thick middle shoot, and a great many smaller ones running from it. In some plants, such as the "carrot," there is a very thick and watery part, with a few very thin and short fibres shooting from it. Such a root is called a "tap-root." But our three plants have "fibrous roots."

The next part of the plant above the root is the stem. In the wall-flower, this is upright, and bears leaves, little branches, and flowers. It is not quite round, but has ridges upon it. If you look carefully, you will find that each ridge runs *up the stem* until it comes to a leaf, when it is

continued along the under side of the leaf; the stem above being for a short distance flat, or without a ridge.

Our buttercup seems to have no stem to speak of; but, in reality, the small swelling just above the root, which looks something like an onion, is a part of the stem.

Very likely you will say the primrose has no stem, for all the leaves and flower-stalks seem to grow out from the top of the root. There *is*, however, a very short and thick stem; but it is so covered up with a number of little brown leaves, called "scales," that it is scarcely noticeable.

Let us now examine the leaves. Certainly those of the buttercup are the prettiest; so we will take them first. We at once discover that there are two kinds on the plant. By far the greater number grow from the bulb near the root. These we will call "radical" leaves; for radical means connected with the root. The others grow higher up, on the flower branches, and are of quite a different shape from the radical ones; and you will note that the lower leaves have long leaf-stalks, or "petioles," while the upper ones have scarcely any petioles at all, and are said to be "sessile." If you spread one of the radical leaves out on a piece of clean paper, you will see what an exceedingly pretty outline it presents. The whole leaf is really in three separate leaflets, each one of which is cut into elegant patterns.

In neither the wall-flower nor the primrose do

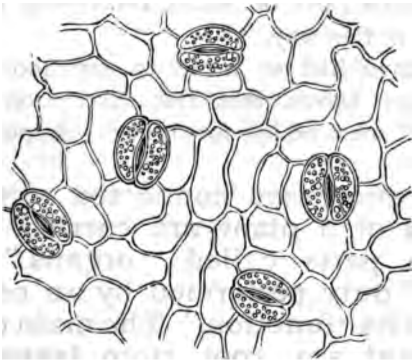
we find the leaves divided into segments. The primrose leaf is certainly notched a little at its edge or margin, but the wall-flower leaf is quite even on its margin, or, as it is termed, "entire." You will notice, also, that the blades of these leaves are continued down on each side of the leaf-stalk, as far as its junction with the stem, so that there appear to be no petioles. In general shape, we may say, the leaf of the wall-flower is long and narrow; that of the primrose long and broad, especially towards the "apex;" and that of the buttercup short and broad, somewhat in the shape of a heart.

Do you remember the story of the boy who had some strawberry plants, and who cut off the leaves to make the strength go into the fruit? He thought by this means to obtain fine strawberries. The boy's experiment, however, was the ruin of the plants. For they all withered away and died of starvation.

This little fellow did not know that a good deal of the food of the plant enters by the leaves. It does so in this manner: You have read that in our air there is a quantity of carbonic acid gas; which, you know, is a result of animal respiration. This gas, we have seen, is composed of carbon and oxygen. It enters the leaves by little openings called "stomata;" and while in the substance or body of the leaf, undergoes a wonderful analysis. It is, in fact, broken up by the power of the sunshine into its elements. The carbon remains in

the leaf, while the oxygen is set free, and returns to the air.

All this is so remarkable that I am sure you would like to have some proof of its truth. From any plant, pluck off a leaf with a long petiole; you had better cut through the petiole with a penknife. Now put the entire blade in your mouth, press the lips tightly round the stalk, which you



LEAF-SKIN, SHOWING THE PORES OR "STOMATA."

must just dip in some water in a tumbler. Now blow hard, as if trying to force your breath into the leaf, of course keeping your mouth shut closely. You will soon see some little bubbles of air form in the water at the cut end of the leaf-stalk. This shows that there must be openings in the leaf through which air has entered; also that this air, having traversed the leaf-blade, has passed down the petiole, and appears as little air-bubbles in the water.

Again, cut some fresh green leaves from a plant that has a rapid growth, say parsley. Place these in a tumbler of clean water and stand the glass in the sunshine. Now watch closely. You will soon see a number of bubbles of air form on the surface of the leaves and rise to the top of the water. These are bubbles of oxygen.

I must tell you that not only the leaves, but all the green parts of plants, decompose carbonic acid gas in this way.

We have had so much to say about roots, stems, and leaves, that the description of the "flowers" must be left for the next chapter.

The processes connected with the growth of a plant are carried on by certain parts called "organs." The special duty performed by an organ is termed its "function." The main organs of a plant are—root, stem, leaves, and flowers. The function of the root is to absorb earthy materials from the ground, to be converted into food for the plant. The leaves and other green parts of a plant decompose carbonic acid gas; retaining the carbon, and setting free the oxygen.

COWSLIPS AND PRIMROSES.

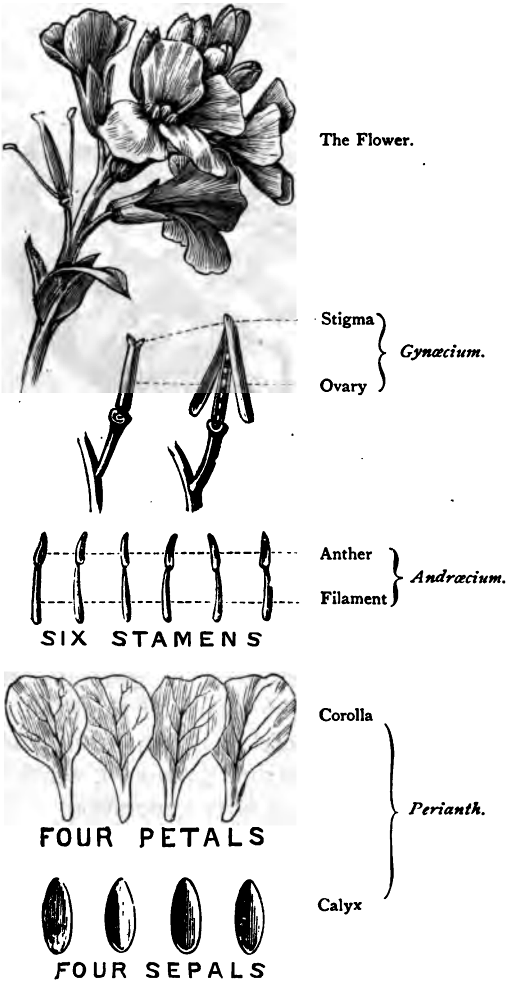
CHAPTER XIII.

PARTS OF A PLANT (*continued*)—THE FLOWER.

THE flower or blossom is generally the most attractive part of the plant. I think we may also say it is a very useful and important part, for by its means the seeds are produced, which continue the plant generation after generation.

We will, as in the last chapter, suppose we have before us the wall-flower, the buttercup, and the primrose. Let us carefully examine and compare their flowers, and try to learn something about them.

FLORAL DISSECTIONS: THE WALL-FLOWER.

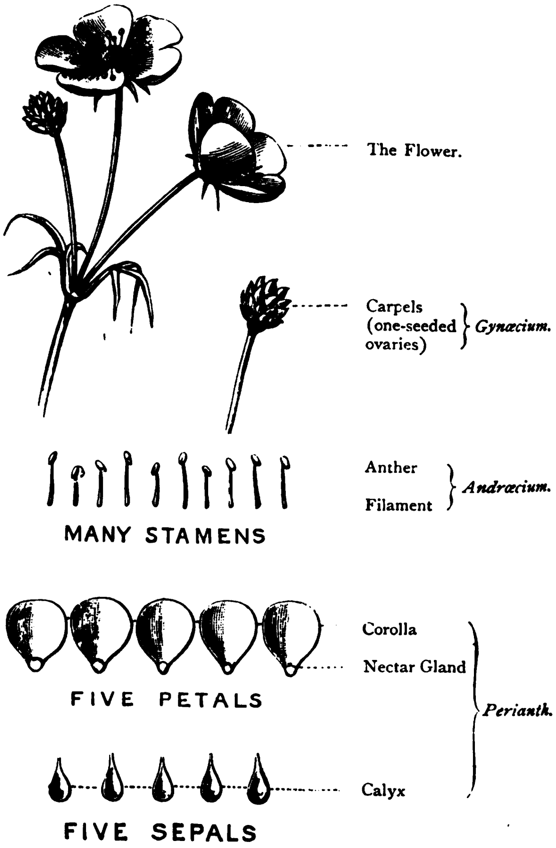


In the first place, we may notice that the flowers of each plant are on thin stalks, called "peduncles." Those of the wall-flower are short, and grow near each other around the upper or terminal part of a stem or branch. In the buttercup and primrose, the peduncles are long, and seem quite distinct from each other; those of the primrose are not on branches at all, but grow up direct from just above the root. In all three cases we find only one flower at the end of each "peduncle."

To examine the flower itself, you should have a sharp pen-knife and a magnifying glass. I dare-say your teacher will lend you a glass, because everybody knows well enough that it is of little use to simply *read* about plants; you must get the plant itself, and look well into it, and find out all its wonderful parts.

Pluck off one of the blossoms of the wall-flower; hold it by the peduncle; take your knife in the right hand, and cut away the outer circle of little dullish-red leaves. You will find *four* of them. Lay them out in a row upon the lower part of a sheet of clean paper. These four form the "calyx," and each one is called a "sepal." Put the remainder of the blossom aside; and now pluck a flower from the buttercup. As before, cut away the calyx. Here there are *five* little "sepals," and they are of a light green colour. Notice also that they are not upright upon the outside of the blossom, but turned back, or reflexed, upon the peduncle. The next time you go into the fields,

Floral Dissections: The Buttercup.

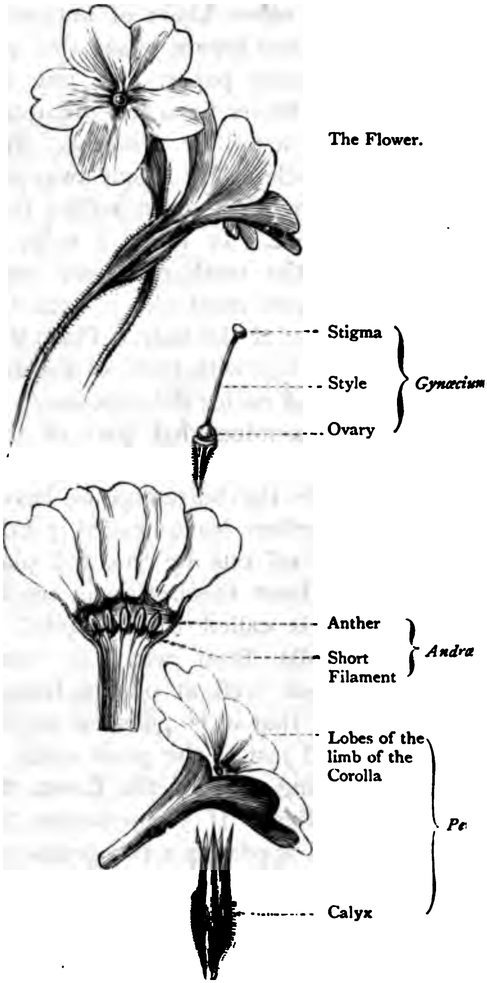


ee whether the other kinds of buttercups have lowers with reflexed sepals. Lay this calyx out, s before, upon the paper, and put aside the emainder of the flower for a few minutes.

Pick off, now, a yellow primrose. It is on a ong, hairy peduncle. Try to cut away the calyx. h! here is something quite unlike the others. t is in one piece. It forms a tube, with *five* rojections like the teeth of a saw on its rim. 'o remove this, you must slit it with the knife, nd then cut away at the base. Place this calyx n the paper in a line with those of the wall-flower nd buttercup, and notice the difference.

Now let us examine that part of the flower ext the calyx, and which is so beautifully coloured i most cases. In the buttercup, we have a circle f five brilliant yellow leaves, called petals. You iay pluck them off one by one, and place them i a row just above the buttercup sepals. The ircle of petals is called the "corolla," and the alyx and corolla form what is termed the perianth." Look well at one of these petals. 'ou will observe that it is polished on the upper r inner side, and just at the point where it unites ith the remaining part of the flower, there is a ery small swelling. If you examine this with our glass, it will appear as a tiny recess or pocket. his is the nectar gland; and in it is the honey iat the wasps and bees are after, when you see iem at work in such a busy and fussy manner pon the flower.

FLORAL DISSECTIONS: THE PRIMROSE.



Look, now, at the corolla of the wall-flower. It forms a cross. Take your knife and carefully remove it. There are four most beautiful and richly-coloured petals. These are rather different in shape from those of the buttercup, for they have stalks by which they are joined to the base of the flower. Lay them in a row just above their corresponding sepals. There are no honey glands to them; but if you take the glass and look at the spot from which you have just removed them, you will find two very bright-green swellings. You can scarcely see them; but the butterfly, with his thousands of eyes and long tongue, knows all about them; for here he finds the honey.

We must now see what the corolla of the primrose is like. First, we notice that it is yellow, but a shade or two paler than that of the buttercup. It seems to be like the buttercup in having five petals. If, however, you try to remove these, you at once discover they are not separate petals at all, but only five broad teeth, or lobes, on the rim of a tubular corolla, which is really in one piece, just like its corresponding calyx. If you take two or three of these lobes between your thumb and finger, and give a smart pull, the entire corolla is easily removed, leaving a curious little thin stalk sticking bolt upright. Of this, however, we shall have more to say directly.

We have not done with our flowers yet. Take up in your hand what remains of the wall-flower blossom. You will remember we have removed

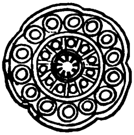
the perianth ; and now we see a circle of very small, thread-like stalks or filaments. There are just six of them ; and you will notice that two are shorter than the rest. At the summit of each, you will find another stalk, much shorter ; this is very small, so use the glass, and you will see a depression or slit down the middle on the inner side. If you touch one of these tiny stalks with your finger, a quantity of light-coloured dust will come off. These six filaments, with the little ones balanced on their tops, are called "stamens." The golden dust is "pollen," and the small summit-stalks are really cases in which the pollen is contained, these cases being called "anthers." The whole circle of stamens is termed the "andrœcium," which you must now remove carefully, and lay out in a row just above the wall-flower "corolla."

Let us now examine the andrœcium of the buttercup. What a number of stamens there are! And how pretty the anthers on their summits look! Here, also, each anther has a slit down the middle. The filaments or stalks are not so long as in the case of the wall-flower. There is a quantity of pollen, and plenty of it may be shaken off. You must remove the andrœcium, and place all the stamens on the paper just above the yellow-petals.

We have now to see what kind of andrœcium the primrose has. Look at what remains of our flower. There do not appear to be any stamens *at all.* Take the glass. There is the thin stalk

standing upright and alone, with a tiny knob on its summit and a beautifully formed little globe at its base. But this is not a stamen, for it has no anther. Are there, then, no stamens to the primrose? Pick up the yellow corolla again. Take your knife and slit down the tube. Lay it open from the slit, and spread it out on the paper. Now you will see where the stamens are. They are upon the inner surface of the tube of the corolla. In the flowers of the blue-bell and lilac and many others, the andrœcium occupies a similar position. In the primrose, there are, you observe, five of these stamens, and they have scarcely any filament; they are nearly "sessile." And now we have come to what I think is the most interesting part of the flower. Take in your hand what remains of our primrose blossom; the little upright solitary stalk, with a knob at its top and a globular body at its base. You have, I daresay, seen a pestle and mortar in a chemist's shop; it is used for grinding and mixing drugs. The pestle is not unlike this part of the primrose flower; and the resemblance has led to the term "pistil" being applied to it. It is, however, not a good name. For only in a few cases is this part of the flower at all like a chemist's pestle. A much better, though perhaps harder word, is "gynœcium." The only hesitation I have in giving you the more difficult term arises from the fact that the explanation of it, as also of the term "andrœcium" must be left for the present.

The little knob at the summit of the gynœcium is called the "stigma." The stalk or filament below the stigma is the "style," and the globe at the base is the "ovary." You may take your pen-knife and cut open the ovary, and then, with the help of the glass, you will have a very pretty sight. Arranged in rows around a central stalk inside this tiny round case, you will see a number of bright, pale, minute, round grains, which, when the primrose is fully grown, are the seeds of the future plants.


OVARY OF PRIMROSE.

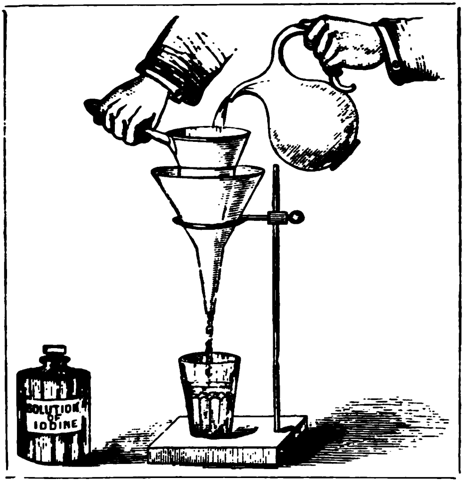
In the wall-flower, you will notice that the gynœcium is somewhat unlike that of the primrose. There is no style, and the stigma is double; the ovary is long and narrow, something like a small pod. It is, in fact, a double pod. If you are very careful, you may open it on both sides with the pen-knife, and you will at once see two rows of seeds.

Now look at the gynœcium of the buttercup. It appears to be a round knob, covered all over with little projections, turning outwards something like hooks. They are called "carpels." Take off one, and examine with the glass. It is not unlike the body and beak of a bird. The hooked part or the beak is really the stigma, and the flat body the ovary. Cut open the latter, and you will find a single seed.

These are all the parts of a flower we need notice at present.

It would be a good exercise for each boy to get the three flowers we have been describing, and make a sort of floral analysis, just as you see in the pictures given in this chapter.

In a fully formed flower there are three main parts—(1) the perianth, consisting of calyx and corolla; (2) the andrœcium, or circle of pollen-bearing organs, called stamens; (3) the gynœcium, which is the central portion of the flower, and contains the seeds.



THE SEPARATION OF POTATO STARCH.

CHAPTER XIV.

PRODUCTS OF A PLANT.

FROM what has been stated in the previous chapter, we learn that plants, as well as animals, require food. But there is a striking difference in the character of the food required in each case. Look at the list of materials which the plant absorbs—carbon, nitrogen, lime, sulphur, flint, iron, etc. Not one of these, in the form it enters the plant, would be of the slightest use as food to any animal. The plant is able to convert these mineral bodies into the material of its own body. For instance, the young plant makes new leaves from them; the tree, fresh wood; the vine, its yearly load of fruit, and so on.

Neither you nor I could form muscle and bone or any other part of our bodies from such mineral food. You know very well that lime, soda, sulphur, carbon, and such like, could not be eaten and digested by us nor by any other animal. What is it, then, which constitutes our food, and whence do we obtain it? You will perhaps say, "Our food is bread and butter, potatoes, meat, and the like." This is true; but when all our food materials come to be examined and analysed, it is found that they consist of but a very few things, such as starch, sugar, gluten, oil, and some others, all of which are found in vegetables. Now, as you are aware, the plant obtains none of these things either from the ground or from the air. Whence, then, does the plant get them? It forms them out of those mineral bodies which constitute its food.

Hence every plant that grows is like a factory, where from certain raw materials a manufactured article is produced. I have been in the engine-room of a cotton mill, and seen how the ponderous engines, which set all the machinery of the factory in motion, are driven by the heat of the great furnaces. And this heat, coming from the coal, is really the stored-up heat of the sun, which shone upon that old forest of which the coal is the remains. Well, it is interesting to think, that the same sun, shining upon our plant-factory, sets all its parts working.

We have very convenient terms for distinguish-

ing the raw materials forming the food of the plant, from those substances elaborated by the plant itself, and which furnish nutriment to animals. We call the former "inorganic" substances, and the latter "organic."

Therefore we may say, in a general way, that the animal kingdom feeds upon the organic substances formed by the vegetable kingdom out of the inorganic matter of the mineral kingdom.

In this chapter we shall describe some of these organic substances.

First in importance comes STARCH. It is found in the seeds, roots, and tubers of plants. A very simple experiment will enable you to prove this. Mix some wheat-flour with a little water and make a dough. Place this in a strainer, and while you knead it in your fingers, let some one pour a little clean water upon it. You will notice that after passing over the dough, the water will become quite milky in appearance. If a little of this be allowed to stand in a tumbler, the water will clear itself, and a white powder will settle. This is starch, and it is derived from wheat. If some of it be boiled in water, it will thicken just like ordinary starch.

Again, scrape a raw potato into a strainer. If a little clean water be poured upon the scrapings, it will, as in the previous experiment, become milky-white, and give a sediment of starch. By this you learn that starch is insoluble in water.

If you have a microscope, you should use it to

look at a little of this potato starch. You will find it is composed of a number of oval-shaped grains or granules, which have markings not unlike those on the outer side of a tolerably smooth oyster shell. Should you be able to procure a little iodine-water, you may mix it with the starch-water; when the milk-white liquid will change in colour, and become a very dark blue, almost black.

Starch is composed of carbon, hydrogen, and oxygen. To form it, the plant has obtained the carbon from the carbonic acid in the air, and the hydrogen and oxygen from the decomposition of water.

SUGAR is another organic substance found in most plants; chiefly, however, in the sugar-cane and beet-root. The plant does not form this compound direct from elementary matter, but from starch. That is to say, the starch, in plants, under certain conditions, becomes changed to sugar. Sugar, like starch, consists of carbon, hydrogen, and oxygen, but, unlike starch, it is soluble in water.

GLUTEN is an important constituent of wheat. When you have washed out the starch from the dough, as described above, the remainder begins to cling to the fingers, or to become "glutinous." This sticky mass consists almost entirely of gluten; which is itself composed of two organic substances called "albumen" and "fibrine." Both these are compounds of carbon, hydrogen, oxygen, and nitrogen.

Let us see how the plant obtains its supply of nitrogen. You will probably think, "surely from the air." But it has been discovered that this is not the case.

In a previous lesson, you read that there was a quantity of ammonia in the atmosphere. Now ammonia is a compound of hydrogen and nitrogen, and is soluble in water. Every shower of rain consequently brings down ammonia from the air to the ground. Here it combines with certain earthy substances, and is then absorbed by the roots of plants.

GUM, WAX, RESIN, CAMPHOR, and OIL, are also formed by plants. Each of these is a compound of carbon, hydrogen, and oxygen.

You must have noticed that the various plant products of which we have been speaking, arrange themselves under two heads. First, we have those which contain carbon, hydrogen, and oxygen; and second, those which, in addition to these elements, contain nitrogen. The former are generally termed "carbonaceous compounds," and the latter "nitrogenous." Along with some of the latter, as, for example, albumen and fibrine, we often find associated, sulphur, phosphorus, lime, soda, and other earthy materials.

Oil is found in the seeds and fruits of many plants. Linseed oil, for instance, is pressed or crushed out of the seeds of the flax-plant. Olive oil is obtained from the juicy part of the fruit of the olive tree.

Plants absorb inorganic materials from the earth and air, and convert them into those organic substances which constitute the food of animals. The products of plants are either carbonaceous compounds, as starch, sugar, gum, resin, oil, etc., or nitrogenous compounds, as albumen, fibrine, gluten, etc.

COWS.

CHAPTER XV.

THE ANIMAL KINGDOM—CLASSIFICATION OF "BACK-BONED ANIMALS"

IN the "First Science Reader," you will remember we divided all animals into two great classes—*backboned* and *boneless*. I did not trouble you then with the proper names for these two divisions; but now that you are one year older, it is time we used them.

The back-bone of animals is not all in one piece, but consists of a great number of separate bones, *placed end to* end, just as you might arrange a *string of empty* reels. Each of these bones is

called a "vertebra," and hence the entire back-bone is called the "vertebral column." All animals which have such a bone are termed "vertebrate animals," or, to use one word, "VERTEBRATA;" and as the prefix "in" means "not," we may call all boneless animals, or perhaps we ought to say "back-boneless" animals, "INVERTEBRATA."

In this and the two following chapters we are going to talk about "vertebrate" animals only.

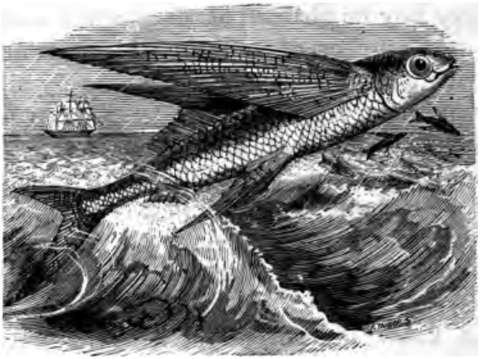
Every boy or girl will at once agree that there are a vast number of animals which are all alike in having a back-bone, but which are very different in many other respects. For instance, a herring and a horse both have back-bones, and are, consequently, both placed in the division "vertebrata;" but there are other respects in which they are so different, that we feel they ought not to occupy the same place in the division. We want, in fact, to carry our classification a little further.

You know that in this school we have two great divisions of the children—boys and girls. But in each division there is a further classification, into standards. And some of these standards are so large, that they again are sub-divided into sections.

Well, in like manner, the whole animal kingdom is divided into two great sub-kingdoms—vertebrata and invertebrata; and these are further divided into classes, and the classes into orders.

I once asked a boy how he would classify all the animals that he knew had back-bones. He said

he would arrange them all in two groups—first, those that could live in water; and second, those that could not. So that he would have in one class fishes only, and in the other class, all the remaining vertebrates. When I told him his second class would be a rather large one, he said he would divide *that* into two parts—first, those that could fly; and second, those that had to keep



FLYING FISH.

upon the ground. You see this boy's classification would really be "birds, beasts, and fishes."

Suppose we had such a division as this, where should we place the bat? This is an animal with a back-bone, and it is also able to fly. Is it a bird? You will answer, "Certainly not, for it has no feathers." But the question is, "What *is* a bird?" It is not enough to say, "A bird is an animal that flies in the air," for a bat does this, and yet is not a bird; and I have even heard of flying fishes.

Again, how should we classify a "frog"? Is it
ι bird, or beast, or fish? In its very young state,
t is, as you know, a fish; we call it a "tadpole."
3ut after a time it can leave the water, and
ɪreathe the ordinary air, and is a fish no longer.
s it a beast now? Here, again, the question is,
What *is* a beast?" Let us take another vertebrate
.nimal—"a snake." This is certainly neither a
ish nor a bird, and yet it would scarcely seem
ight to place it in the same class with cows and
ιorses, and other beasts.

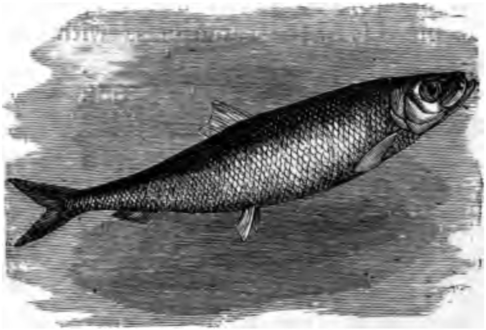
Before we can classify any set of objects, whether
ɪack-boned animals or other things, we must
lecide upon some particular points according to
vhich we shall make our classification.

You will remember reading in the "First
Science" book, that we arranged the boys into
tandards, according to how much they knew or
vere capable of learning. In other words, the
basis," as it is called, or the "principle" of our
lassification was the capabilities of the scholars.
'erhaps you will think this the only basis we could
dopt. But, as a matter of fact, the boys might
ave been classified according to their height, or
ıeir age, or the colour of their hair. You see by
ıis, that we may have a choice among a great
umber of bases of classification.

The question we have to ask ourselves is simply
ıis,—Upon what principle shall we group the
'hole sub-kingdom vertebrata?

You have read that animals possess certain

organs. A dog, for instance, has lungs for breathing, a heart for circulating the blood over all parts of its body, eyes for seeing, and so on. But these organs vary very much in different vertebrate animals. The heart of a frog is quite different from that of a pigeon; while that of a salmon differs from either. The lungs of an eagle are unlike those of a bat, while each of these animals



HERRING.

have breathing organs not in the least resembling those of a herring.

Suppose, then, we classify all vertebrate animals according to the build or structure of their most important organs. On such a plan we shall be adopting as the basis of our classification what we may term "organisation." The boy who grouped the vertebrata into animals that swam in water, flew in air, or walked upon land, was *adopting*, as his basis, the "habits" of the animals.

Well, taking the build of the most important organs as our basis, the whole sub-kingdom vertebrata is divided into five classes:—(1) mammals, (2) birds, (3) reptiles, (4) amphibians, and (5) fishes.

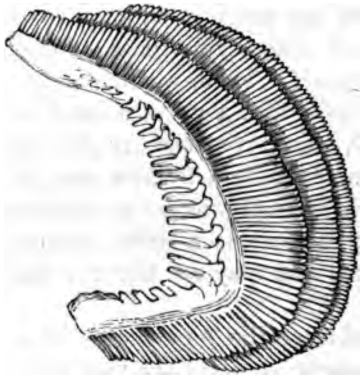
We will begin with the fifth class, and try to discover what are the chief characters in the organs of a fish. When we were describing the different parts of a flower, you will remember I advised each boy to get a common plant, and with pen-knife and magnifying-glass examine all those parts for himself. Well, we ought to do the same with a fish, of course I mean a dead one.

Probably, when your teacher gives you a lesson upon this subject, he will show you, by dissecting a fresh herring, the organs we are about to describe; and it may be there is a little aquarium in your school, where you may see the live fish swimming about.

If you observe the movements of a fish in one of these aquaria, you will see that it is continually swallowing mouthfuls of water, which pass out again at the side of the head through a slit behind a sort of flap.

If you get a fresh herring and cut away one of these flaps, you will find under it, four rows of very red flesh, in the form of fringes, one above the other, the largest being at the top. These are "gills." They are the organs by which the fish absorbs the oxygen from the air of the water, in its passage over them from the mouth.

You must understand clearly that the fish does not breathe the oxygen of the water, for no animal that I know of has the power of decomposing water into its elements. But there is always a certain amount of our ordinary air dissolved in water. It is *this* air which the fish breathes; the same air, in fact, which we breathe, and which, you know, is a mixture of nitrogen and oxygen.



GILLS OF FISH.

In course of time, fishes use up the oxygen from the water, just as we use up the oxygen from our air. And it is just as fatal to the fish to be breathing the same water over and over again as it is for us to be breathing the same air. You see, therefore, why it is often necessary to change the water in an aquarium.

We may here notice a very interesting fact.

There is always a quantity of carbonic acid gas in water. Not only is this gas brought down from the atmosphere by every shower, but all water animals produce it by respiration, as we do. Well, aquatic plants absorb this gas, decompose it, retain the carbon and liberate the oxygen; so they render the same service to the fish as aërial plants render to land animals.

But why does a fish require oxygen? For precisely the same reason as *we* require it—to purify the blood. You know that impure, or venous blood, from all parts of our body, finds its way to the heart. The heart pumps it into the lungs; there it meets with the oxygen of the air we have breathed, and becomes pure arterial blood, which is then distributed all over our bodies, to make a new stock of muscle, bone, and other things.

In like manner the venous blood of the fish finds it way to the heart; which at once pumps it on to the gills, where it meets with oxygen, and is converted into pure arterial blood of a bright red colour.

If your teacher shows you the gills of a herring, he will very likely point out to you the heart, lying just under the lowest gill-fringe. This little heart has two chambers; the smaller one is called the "auricle;" and into this, the blood from the body is poured. The larger one is called the "ventricle;" from this the blood is pumped to the gills. After leaving the gills, the arterial blood does not flow

back to the heart, but into a pipe called the "aorta," from which it is distributed all over the body of the fish.

The "fins" form a distinguishing feature of fishes. You will notice, in the case of the herring, one pair of fins near the gill-slits, a little farther back. These are the "pectoral fins," and correspond with the wings, fore-legs, or arms of other vertebrate animals. Then there is the pair of ventral fins, on the under part of the fish's body, about four inches nearer the tail than the pectorals; these correspond with the hind limbs of other animals. You will find other fins, but they are not in pairs, and cannot be considered limbs at all.

You must have noticed that fishes have "roes;" some hard, and others soft. The hard roe consists of an immense number of little eggs, which the female lays in some quiet corner among the water weeds, and which, in course of time, become fishes.

If you remove a roe from a fish, you will see, lying right along the body, close up against the back-bone, a long, narrow, silvery bag. This is the "air bladder." It is thought that the fish is able to fill this with air, and empty it, at pleasure. If so, then this air-bladder seems to be the beginning of a sort of lung.

Just one more fact about fishes. Their skin is not covered with hairs like the skin of beasts, nor with feathers like that of birds, but with bright, shining scales.

Now I think we have said all that is necessary

fishes. In the next chapter we will talk amphibians and reptiles.

rtebrate animals are divided into classes—mammals, birds, reptiles, ıibians, and fishes.
shes are vertebrate animals that he the air dissolved in water, by ıs of gills. The heart is two-ıbered, and the blood red. The s, when present, are in the form of and the body is covered with scales. young are hatched from an egg.

THE FROG.

CHAPTER XVI.

VERTEBRATE ANIMALS—AMPHIBIANS AND REPTILES.

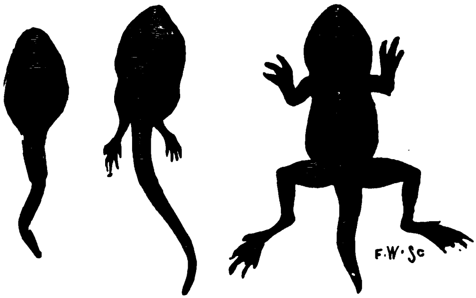
NEARLY every English boy has seen a frog; an nearly every English girl considers it a very nast creature. But the only reason for people thinkin so meanly of this animal is simply that they d not understand it. There is not a single being i the entire animal world which forms a mor interesting subject of study than the frog.

It is an excellent swimmer, and if any bo wishes to know how to dive, let him notice how frog enters the water. Observe, also, the action o a frog's hind legs when swimming; it is a perfec model of the best way of "drawing in" an "striking out." I often think a frog ought to b decorated with the gold medal of the Londo Swimming Club. Boys who love swimming—an he must be a queer sort of boy who does not—*surely* must feel considerable interest in so ex*cellent a swim*ming master.

I should certainly advise you to look about

ponds for a little group of frog's eggs; frog's spawn, as it is called. It has the appearance of a mass of jelly at first; but, in course of time, eggs can easily be distinguished. When you have obtained some, place it in a large glass bottle of pond water; if possible, with the water-plant to which you probably found it adhering.

In a few days, curious little fish are hatched. These are the "tadpoles" which every boy knows. They are lively little creatures, swimming about



THE TADPOLE AND ITS CHANGES.

rapidly by means of their long tails. The head is so large, as to seem out of all proportion to the other part of the body. In fact, the animal appears to be all "head and tail." Now, this creature is a true fish; that is to say, it breathes water-air by means of gills, and has a two-chambered heart.

You should watch these "tadpoles" day by day. Two little gills are at first plainly distinguishable on either side of the large head. These, however, soon disappear. Afterwards the hind legs begin

to grow. Then the tail gets smaller and smaller, and two small arms or fore-legs are seen. All this time a very remarkable change has been going on inside the little creature. True lungs for breathing the air as we breathe it have been gradually forming. And, what I think most wonderful of all, another chamber has been added to the heart, which now has three chambers.

But this is not all. The fish-like gills have been getting smaller and smaller, and the tadpole begins to find a difficulty in breathing the water-air. But one fine day it pokes its nose out of the water altogether, and finds, no doubt to its astonishment, that it can breathe in the air! A new life has come upon it! It sees no particular reason now for spending all its time in the water. So it swims to the bank of its pond, crawls out upon dry land, sits down upon its haunches, surveys the world, and breathes as freely as any man. It is now no longer a fish. It has entered upon a higher stage of existence, and has become a "frog."

Here, then, we have a creature that has two distinct kinds of life—one, that of a fish; and the other, that of a land animal. Toads and newts pass through similar changes. Such animals are called "amphibians," a word which means "both-lives."

When I first took a frog up in my hands, I was surprised to find it so cold; as cold as a fish. *This is because* amphibians, like fishes, are cold-

blooded animals; the coldness of the blood arising from the fact that it absorbs so little oxygen.

The three chambers of the frog's heart consist of two auricles and one ventricle. The venous blood from the body of the animal enters the right auricle, then passes to the ventricle, whence it is pumped into the lungs. After meeting with the oxygen of the air, it becomes pure arterial blood, and then passes to the left auricle. From this chamber it is forced into the ventricle. There is consequently in the one ventricle of an amphibian, a mixture of venous and arterial blood, and it is this half-oxydised blood which is distributed all over the body.

After this description, I think you will all agree in thinking that the frog is an exceedingly interesting little creature; and yet I have not told you near all of the wonderful things about it, which I hope you will learn by-and-by.

You will often hear frogs, toads, and newts spoken of as "reptiles;" but they are not such, strictly speaking. A true reptile has not been, in any part of its life, a fish. It breathes in air from the time it is hatched from the egg, until its death. It never possesses gills.

The class "reptiles" includes tortoises, turtles, snakes, lizards, and crocodiles. Besides breathing by means of lungs, reptiles generally have their skin covered with plates; and the one ventricle of the heart has a sort of skin, or membrane, passing partly down the middle, so as to nearly divide

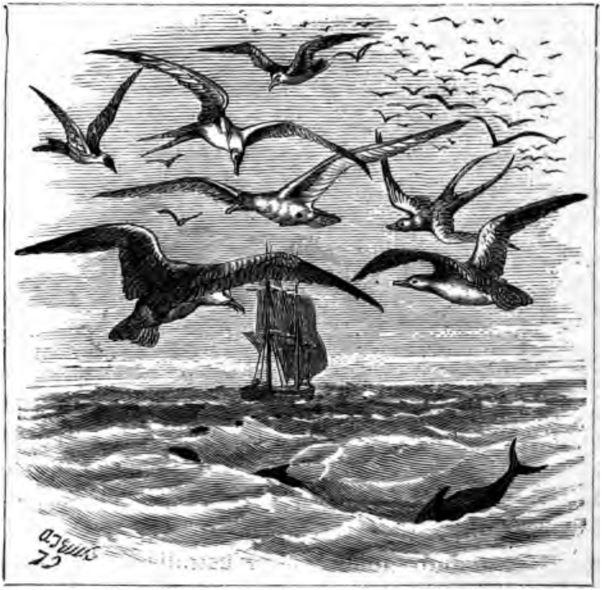
it into two parts. In the highest of the reptiles, namely, the crocodiles and alligators, or caimans, this division is quite perfect, so that *their* heart is four-chambered.

Most reptiles have four limbs. These, in the case of the turtles, are formed for swimming. Nearly every boy has seen, and perhaps handled, a tortoise. These creatures are very slow in their movements, and seem to be only half alive. The head and feet are protruded a little way from out of a hard shell or box, which consists mainly of two portions, an upper and a lower. Tortoises have no teeth, and can live for a long time, even years, without food.

Amphibians are vertebrate animals which, during the earlier stage of their existence, breathe by means of gills, like fishes; and like them also possess a two-chambered heart. In their adult life, amphibians have true lungs, and a three-chambered heart. They have four limbs formed for swimming, and a skin free from scales.

Reptiles always breathe atmospheric air by means of lungs. They are provided with a three or four-chambered heart, and their skin is covered with plates or thickened scales.

The young of both amphibians and reptiles are hatched from the egg.



GULLS AND FISH.

CHAPTER XVII.

VERTEBRATE ANIMALS—BIRDS AND MAMMALS.

ONE of the greatest pleasures of a boy's life is to keep pigeons. And the happiest expression of countenance I ever saw was that of a little girl who, one bright spring morning, ran to her canary, and her canary hopped down from its perch to her, and placed its delicate beak between the rosy lips of its young mistress.

There is nothing surprising in the fact that

people are so fond of birds. They are the most beautiful of all animals, and their voice is the most pleasing. Birds not only delight the eye by the gorgeous colour of their feathers, but also charm the ear by the sweetness of their song.

It is a good thing for a boy or a girl to keep birds, if they will only look well after them and not get tired of attending to them.

Let us endeavour to understand the nature of the chief organs of a bird, and see in what respects it is unlike other vertebrates. You will doubtless say, "A bird can fly, and that distinguishes it from other back-boned animals." But a bat can fly, and yet is not a bird; and there are some birds which cannot fly, such as the emu and ostrich; there is a bird found in Australia, called the "apteryx," which has not even wings.

I will tell you the main characteristics of a bird.

First, it has lungs which are fixed to the ribs, and which open into a number of air-sacs in various parts of the body; these air-sacs even lead into the hollow of some of the bones. Hence, a bird is able, not only its fill its lungs with air, but also to admit air to its very bones, and to other parts of its body. Two results follow from this:—(1) it is exceedingly light as compared with the size of its body; (2) its blood, coming in contact with so much air, absorbs a large quantity of oxygen, and is consequently very *warm. This, you* see, is quite sufficient of itself

to separate the class "birds" from the cold-blooded reptiles, and amphibians, and fishes.

Second, the heart of a bird has four chambers, —two auricles, and two ventricles. The auricle and ventricle on the right side are engaged in receiving the venous blood from all parts of the body and pumping it to the lungs. The left auricle and ventricle receive the arterial from the lungs, and pulsate it all over the body. Hence we learn that in a bird there is no mixture of venous and arterial blood as there is in the heart of a reptile.

Third, a bird has four limbs; but the front ones are, in nearly all cases, modified into wings. If you should ever see the bones of the wing of a bird, you will find that they quite correspond with those of the fore-limbs of other animals.

Fourth, the skin of a bird is covered with feathers. This is a very characteristic feature, for no other animal has feathers.

There is one respect in which birds are like reptiles, amphibians, and fishes. Their young are hatched from an egg

As to the food of birds, it is well to remember that some are "carnivorous," or flesh-eaters, like the eagle, vulture, and other birds of prey; some are "granivorous," or grain-eaters; some, "insectivorous"; and some "omnivorous."

Only the male bird has the power of song. It is his way of making love to his mate. But he will not sing if he is in trouble, or ill, or there is

a storm coming on. It seems that birds really understand one another. For if a number of them are gaily singing in the woods, and a hawk or other bird of prey appears, the songster who first perceives the enemy, utters a shrill note; when all at once the chorus stops, the singers vanish and hide themselves, and the bird-eater finds himself alone in the silence.

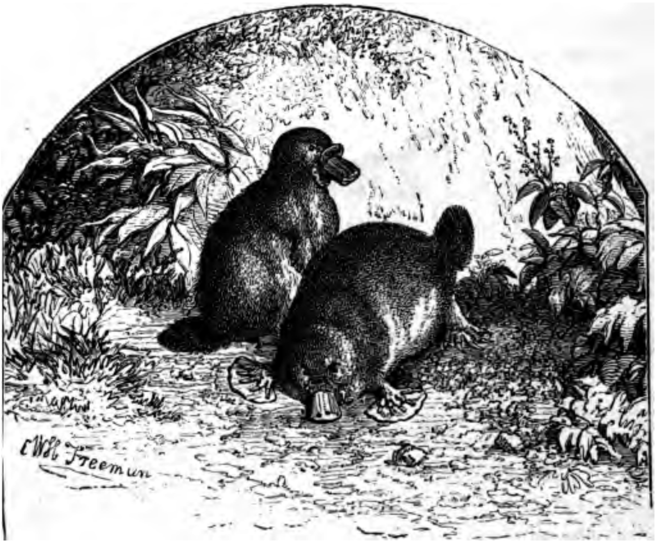
The first and highest class of vertebrates are the "mammals." If we were to write out the

THE SPARROW-HAWK.

names of all the members of this class, the list would be a very long one. Let us see what it would include. At the bottom of it we should place that remarkable Australian animal the "ornithorhynchus." If you saw this creature, you would probably think it a bird; for it has a beak just like that of a duck. In fact, the word "ornithorhynchus" means bird-beaked. And there *are* other points of resemblance to birds, besides *its beak.* Yet it is not really a bird; for it has

no feathers, does not lay eggs, nor admit air to other parts of its body from the lungs.

A little higher on the list, we have kangaroos and opossums, curious creatures, whose young, when born, are scarce fully-formed; so the mother pops them into a bag or pouch, where they pass



THE ORNITHORHYNCHUS.

their babyhood. In pictures, you may see represented this pouch in front of the animal; it is formed by a fold in the skin.

Still higher on the list, we have "whales:" Perhaps you will say "whales ought not to be *here*, they ought to be classed among the fishes." Why

ought they? Is a whale a fish? Let us see. A fish breathes by means of gills. Now a whale breathes the air the same as *we* do, namely by lungs. It never has gills. Again, the heart of a fish has two chambers, and its blood is cold; while in the heart of a whale there are four chambers, and its blood is warm. Still further, the fish lays eggs, from which its young are hatched; the whale never lays eggs, but brings forth its young alive. Lastly, a fish has fins, and its body is covered with scales; whereas a whale has no true fins, and if there is any covering on its skin, it is in the form of hair. Does any boy now think the whale a fish? I should say not. Then why do some people call it a fish? Simply because they have not settled in their minds what a fish really is. It lives in the *water* certainly; but that is only because it finds its food there.

Occupying a position still higher on our list of mammals, we have the "hoofed animals," such as the rhinoceros, tapir, horse, ass, ox, sheep, goat, etc. Then we come to the elephants; and higher still on the list, will appear the "carnivora," or "flesh-eaters," as, for example, the seal, walrus, otter, bear, wolf, dog, fox, tiger, cat, lion, etc. Very near the head of our long gradation we find the bat and mole. The topmost place but one is occupied by the monkey, orang, chimpanzee, and gorilla; these three last ones being "tailless *apes.*"

At the summit of this great ladder of animal

forms, stands "man" himself, the lord of them all; fitted by the possession of a marvellous "mind" to "have dominion" over all the others; and yet capable of sinking lower, in many respects, than most of them.

Now let us see in what way the "mammals" are

SHAKESPEARE.

distinguished from the other four classes of the vertebrata.

There are three main points of difference. First, they all bring forth their young alive, and nourish them for a time upon a special fluid—milk, which is formed in the body of the mother.

It is for this reason the class is named "mammalia," for the word "mamma" means "a breast."

Second, the lungs never communicate with air-sacs, and are not fixed to the ribs, as in birds, but freely suspended in the chest.

Third, some part or other of the skin is always provided with hairs at some time of their life; never with feathers, or plates, or scales.

I must tell you that there is one important part of the animal which has been purposely omitted from our description. We have said nothing about the skeleton or bony framework. Now, although this framework is built up upon the same general plan in all the vertebrates, yet there is some variation in that plan in each of the five classes. But this is a part of the subject that we must leave for a more advanced book than this is.

You will often hear "mammals" spoken of as "quadrupeds," a word which means "four-footed." It is not a good name for them. It surely cannot be said that a whale has four feet. A monkey has two hands certainly, if not four. And besides this, some reptiles and amphibians undoubtedly have four feet; for instance, crocodiles and frogs.

Birds are vertebrate animals having lungs which communicate with air-sacs in various parts of the body. Their heart is four-chambered, and the blood *warm.* Their fore-limbs are modified *into wings* for flying, and the skin is

covered with feathers. The young is hatched from an egg. Mammals are vertebrate animals whose lungs are freely suspended in the chest, and do not communicate with air-sacs. The young is brought forth alive, and nourished for a time on a special fluid called milk, formed in the body of the mother.

LIST OF THE MOST DIFFICULT WORDS OCCURRING IN THIS BOOK.

NOTE.—*The meanings here given explain the words as they are used in the text only. It is intended that the scholar shall commit this list to memory.*

analyse, to separate into parts.
ascertain, to find out.
accomplished, done.
aqueous, watery.
atmosphere, the air.
ascend, to go up.
adhering, being close together.
absorbs, draws up.
apex, the top.
brilliantly, very brightly.
barometer, an instrument for measuring the weight or pressure of the atmosphere.
constitutes, makes up.
crystalline, in the form of a crystal.
completely, quite.
colourless, without colour.
combustion, burning.
compressed, forced close together.
continuous, not ending.
conversion, change.
carnivorous, flesh eating.
diluted, mixed with water.
disappear, to go out of sight.
decompose, to separate into parts.
decorated, having ornaments.
endeavour, to try.
extinguished, put out.
elapsed, passed.
extract, to take out.
enormous, very great.
examine, to inquire into.
expand, to swell out, or enlarge.
equivalent, equal.
elaborated, worked up.
fragment, a piece.
fibres, small threads.
gradually, step by step.
graphite, black-lead.
gaseous, in the form of gas.
gorgeous, beautiful in appearance.
granivorous, grain-eating.
hap-hazard, by chance.
issuing, coming out.
invisible, that which cannot be seen.
inflammable, that which we can inflame.
indestructible, that which cannot be destroyed.
inquisitive, wishing to know fully.
intervenes, comes between.
invertebrata, animals without back-bones.
insectivorous, insect-eating.
liberate, to set free.
museum, a collection of objects illustrating the arts and sciences.
magnificent, very grand.
myriads, great numbers.
malleable, able to be hammered out.
multitude, a great number.
nutriment, food which nourishes.
occupy, to fill.
operations, works.
previously, before.
performed, done, acted.
ponderous, heavy.
purify, to make pure.
resemblance, likeness.
respiration, breathing.
reflexed, turned back.
sandstone, stone formed from sand.
specimens, examples.
sediment, that which settles in a liquid.
thermometer, an instrument for measuring heat.
temperature, degree of heat or cold.
tubular, like a tube or pipe.
variations, changes.
vertebra, a portion of the back-bone.
vertebrata, animals having back-bones.
windward, the direction from which the wind blows.